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THE THEORY AND CONSTRUCTION OF THE LEADING FORMS OF ELECTRO-MOTORS, AND THEIR EMPLOYMENT IN THE PRODUCTION OF THE ELECTRIC LIGHT.

By Prof. HENRY MORTON, Member of the Light-House Board.

II.

THE LONTIN MACHINES.

Among the machines for generating electricity that have commanded more or less of general attention may be included the magneto and dynamo-electric machines devised by Lontin. In their mode of construction and arrangement these machines possess features which recall the Alliance and Holmes magneto-machines on the one hand, and the Siemens and Gramme dynamo-machines on the other.

There are two styles of Lontin dynamo machines, the one yielding continuous currents of one direction, and the other producing alternating currents.

In the machine of the first form, a number of bar electro magnets are disposed radially about a central shaft of soft iron, and the star-shaped wheel thus formed is made to revolve between the poles of an ordinary powerful U-shaped electro magnet. The wire of the electro-magnet wheel forms one complete circuit, and is connected at the several points of juncture of each two successive magnet coils, with the appropriate section of a commutator, placed upon the axis of the machine. On revolving the wheel between the poles of the stationary upright field magnet it will readily be seen that, considering any individual radial electro magnet, there will be induced in the coil of the latter, during its motion away from one pole and its consequent approach to the opposite pole, a current which, though varying (first diminishing and then increasing) in intensity, will still maintain a constant direction until the coil has arrived at the opposite pole, where a reversal of the current will take place. The current will continue flowing in this new direction until the revolution of the wheel brings the coil back to the pole from which we have considered it to start, when and where the current will be restored to its former direction. At any moment, therefore, during the revolution of the wheel, all the electro-magnet coils in the upper half of the wheel will be traversed by a current flowing in one direction, and all those in the lower half by one in the opposite direction. Elastic strips, one on each side, bear against the commutator in the line where the reversal takes place, and lead away the currents to the proper binding-posts. The mode of generation and direction of the currents in this form of the Lontin machine is thus seen to be exactly similar to that obtaining in the Gramme machine.

The stationary electro magnets are

included in the main circuit, in accordance with the dynamo-electric principle. By mounting several of these wheels of electro magnet, with separate comutators and field magnets, on the same central shaft, an equal number of independent currents may be obtained, which by appropriate means may of course be combined in any desired manner.

By winding the alternate electro magnets on each wheel in opposite directions, the machine may be made to produce currents constantly varying in direction. The Lontin machine proper, for alternating currents, has, however, a more elaborate form, bearing a rather close resemblance to the machine devised by Holmes.

This Lontin machine consists essentially of an electro-magnet wheel, like that in the first described form of the machine, only that the magnets are much more numerous, amounting in number to twenty-four and over, and are wound in the manner just referred to—that is, the alternate magnets are wound in opposite directions; and of a large stationary soft iron ring surrounding this wheel concentrically, to which ring there are secured, at equal distances apart, a number of short electro magnets, equal in point of number to the electro magnets on the inner wheel. The electro-magnet coils of the revolving wheel are connected together, so as to form one circuit. The current necessary for the saturation of these magnets is obtained from an auxiliary machine (a Lontin machine of the first form, for instance), mounted upon the same axis, connections being so made, by means of brushes and collars, that the rotation of the large wheel does not interfere with the circulation of this current. The ends of the electro magnets, during the rotation, pass very closely by the cores of the outer stationary magnets, and as the successive magnets on the wheel present opposite poles to the cores, constantly alternating currents are induced in the outer magnets. One series of terminals of the coils of these magnets is led to one binding post, while the other passes to a set of circuit-closing devices, by means of which all of the currents, separately or together, or any individual one or ones, may be conducted away from the machine.

The great merit of this second form of the Lontin machine lies in the facility with which currents varying in number and intensity may be derived from it, so that quite a number of electric lights may be produced at the same time, and also in the fact that in the conducting away of these currents contact brushes are entirely dispensed with; so that the great loss in electricity attendant upon this mode of collection, besides the frequent attention required by its use, is entirely avoided.

With a velocity of rotation of 320 turns per minute, the machine being arranged so as to yield 12 separate currents, the outer magnets being connected together two and two for this purpose, 12 lights were obtained, each equivalent to 740 candles. Three series of 8 magnets each gave 3 lights, each having an intensity of 1,480 standard candles.

It is said that to prevent any detriment to the machine arising from the conversion into heat of any currents that may not be required, while the remaining ones are being applied to some special purpose, these superfluous currents are made to pass through appropriate resistance coils, and thus become in a manner absorbed.

This may of course prevent such mischievous or destructive effects, but in no wise diminishes the loss of efficiency involved in the production of this amount of electric energy, from which no useful effect is obtained.

A large Lontin machine of the kind last described was used at one time for lighting the railway depot at Lyons, where it fed 31 separate lamps, each giving out a light of about 340 candles. The power needed to run this machine is not stated. Another machine of this form, giving 24 lights of 1,480 candles, required from 20 to 22 horse-power to drive it. Smaller machines, of from 2,000 to 3,000 candles, demand somewhat more than 5 horse-power.

SIEMENS NEW MACHINE.

Siemens and Halske have lately devised a new dynamo-electric machine, for the production of one or several independent currents, which may be made, at pleasure, either intermittently unidirectional or rapidly alternating in character.

In one form of this machine the two sides of an upright iron frame carry each a series of 8 circularly disposed electro magnets, the cores of which stand out at right angles to the sides, and carry at their ends, where they face the corresponding cores of the opposite series, large, flat plates of soft iron. The plates of each set are alternately of opposite polarity, while those facing each other exhibit the same polarity; and as the space between them is made as small as the mode of construction will permit, magnetic fields of high intensity and of alternately opposite polarity will come to be formed.

Upon a shaft running through the center of the frame there is secured a disk, carrying on its circumference an upright iron ring, oblong in section, made either of wire or plates, sometimes also of massive iron. This ring is surrounded at eight (or more, in some forms of the machine) equi-distant places by flat coils of insulated copper wire, which, with the ring, are carried by the

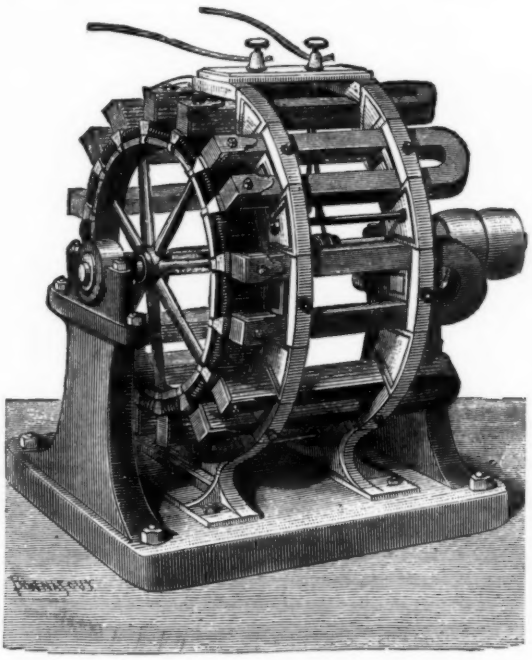


Fig. 37.

rotation of the shaft through the magnetic fields formed by the electro magnets. Two of the coils on the rotating ring are devoted exclusively to the purpose of keeping the field magnets saturated, in accordance with the well-known dynamo-electric principle; and since the current in this case must be constant in direction, a special commutator is provided to secure this result. The alternating currents obtained from the remaining coils are conducted away from the machine by means of collars and brushes in the ordinary manner.

The great resemblance of this machine to a machine of the Brush form, in which eight sets of electro magnets are employed, instead of the usual two, need scarcely to be pointed out.

Several forms of the machine above described are manufactured by Siemens and Halske, the details varying with the purposes to which it is intended to apply any particular machine. The larger ma-

chines possess one important distinctive feature, in that no iron is made use of in the construction of the revolving disk, the cores of the coils being formed of wood or some other non-magnetic material. By this mode of arrangement the hurtful inductive effects, the production of Foucault currents, the loss of power by conversion into heat, and the like, attendant upon the use of iron in this connection come to be entirely avoided.

THE DE MERITENS MAGNETO-ELECTRIC MACHINE.

While most of the recent inventors and improvers of magnetic machines have abandoned the use of permanent magnets, one, M. De Meritens, has thought best to return to this feature of the earlier forms. There is certainly this to be said in its favor, that if equal power in permanent magnets could be obtained without too great cost of material and inconvenience, a machine so constructed would be theoretically more economical than one on the dynamo-magnetic principle, since the energy expended in producing and maintaining the magnetic force of the field magnets in such a machine is a total loss as regards the ultimate available current from the machine.

The difference between a magneto- and a dynamo-electric machine in this view would be essentially like the difference between a watch whose spring, being wound up in the usual way, was

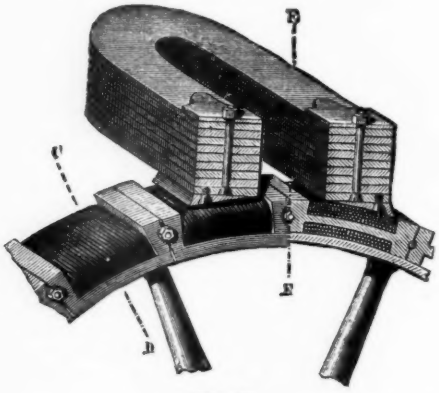


Fig. 38.

prevented from running down or unwinding at the inner end by a ratchet, as is usual, and one in which this unwinding was prevented by the constant motion of a friction coupling of some sort. In other words, in the dynamo machine, we substitute energy as a retaining power for the mere statical force supplied by the permanent magnet. The energy costs something all the time, the statical force nothing but what is involved in the first cost of material.

It might therefore be asked, why dynamo machines, as a rule, were, in fact, more economical in working than the early magneto machines, such as the Holmes and Alliance machines.

The obvious reply is that the enormously greater power which could be concentrated in the electro magnets of the dynamo machines diminished their weight, size and number of parts in a like degree, and so reduced the losses from friction, resistance of conductors, and the like, which exist in the large, heavy, and multisectional magneto machines.

If, however, it should become possible to make permanent magnets equal in power to the field magnets of the dynamo machines, then, undoubtedly, a machine constructed with such magnets would possess decided advantages as regards "duty," or economy of driving force.

The De Meritens machine seems to be an effort in this direction. It consists of

a series of powerful steel magnets, built up of thin plates, as shown in Fig. 38, supported in a circular frame, within which revolve a series of coils mounted on the periphery of an interior wheel, as shown in Fig. 37.

Though great claims have been made for this machine, it does not seem to differ sufficiently from the earlier magneto-electric machines to account for any such great superiority in results.

In addition to the other machines which I have already mentioned are several which should by no means be passed over without notice.

Thus, in the first place, Mr. Edward Weston, of Newark, N. J., is manufacturing a machine which in general appearance so closely resembles that of Siemens, shown in Fig. 24, that this wood-cut would answer very well as a representation. There are, however, several important differences of construction and interior arrangement, and a careful series of experiments, as will appear further on, has shown that its performance is very remarkable as compared with the Siemens and other forms which have been here tested.

Another machine which has met with some success in practical application is that manufactured by Messrs. Arnoux & Hochhausen. In general structure it much resembles the second form of the Wilde or the Farmer-Wallace machine.

In describing the various forms and modifications of these machines I have not attempted in all cases to follow the chronological order of each step, as this would sometimes have involved the skipping about from one type of machine to another. I will now, therefore, give an abstract of the chronology of the subject, following Dr. Schellen's book already quoted, and to which I am indebted for many of the engravings of machines, &c., with which this report is illustrated for a part of the list:

1831. Faraday discovered magneto-electric induction.
1832. Pixii made first magneto-electric machine.
1833. Saxton made magneto-electric machine.
1833. Clarke made magneto-electric machine.
1849. Nollet-Van Malderen, Alliance machine.
1852. Holmes improved form of above.
1857. Siemens introduced peculiar armature.
1864. Pacinotti, the first continuous-current machine.
1866. Wilde made his first form of machine.
1866. Siemens & Halske, same principle as Ladd.
1867. Ladd, self-exciting principle.
1867. Wheatstone developed same principle.
1871. Gramme first described his continuous-current machine.
1873. Wilde describes his second form.
1875. Siemens describes his machine.
1873. Farmer patented machine like Wilde's second.
1874. Lontin machine, for many circuits.
1878. Gramme's alternating machine.

In considering the application of the electric arc as a source of light, it becomes very important to notice with accuracy just what is the chief location of light in the ignited poles, and how this may be affected by various conditions.

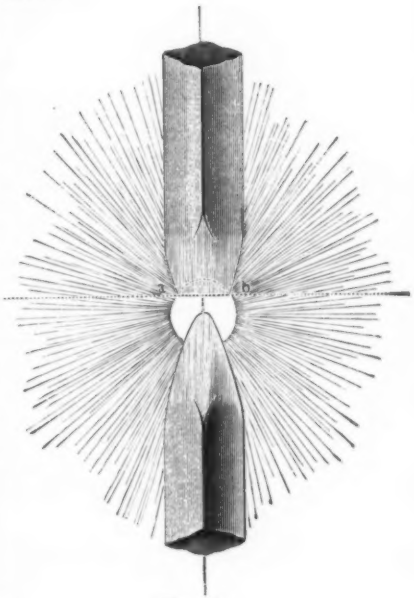


Fig. 39.

Thus, in the first place, if we are using a machine with a current of uniform direction, we will find that the upper or positive pole, as they are generally arranged, soon acquires a cup-shaped form, as shown in Fig. 39, and that the most intensely luminous portion of the carbon is the interior of this positive cup. The edges of this cup will evidently cut off this light from spreading upward for a very considerable angle, while on the other hand all the light from this interior luminous area

will pass freely downward. From this it will of course follow that very different results would be obtained if, with such machine and arrangement of the carbons, the lights were measured from below, or on a level, or from above.

If the two carbon points are not placed truly in line with each other then we have such a state of affairs as is shown in Fig. 40.

Here, evidently, while the light from the hollow positive pole would radiate freely in front, it would be largely cut off behind, and escape only with a medi-

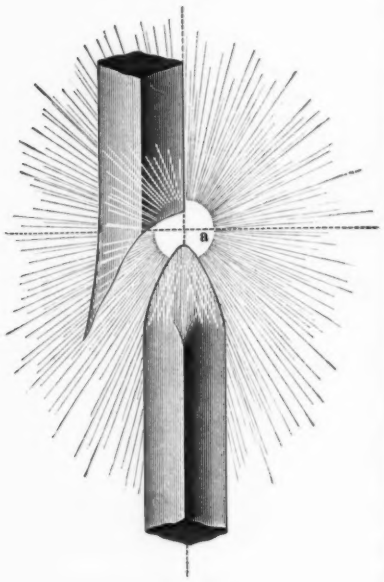


Fig. 40.

um degree of facility at either side; in fact, measurements made with such arrangement show the following figures:

Representing by 100 the light emitted, in a horizontal position, when the points are in line, we have for the various directions, when they are displaced as shown in Fig. 40: In front, 287; laterally, 116; backward, 38.

In the report of experiments made by a committee of the Franklin Institute (see Journal of that Society, vol. 75, p. 301) I find the record of a similar set of measurements as follows:

Front	2,218	candles
Side	578	"
Side	578	"
Back	111	"

3,485÷4=871

"The light produced by the machine, under the same conditions, except the carbons being adjusted in one vertical line, was 525 candles. This would seem to indicate that nearly 66 per cent. more light was produced by this adjustment of the carbons; but a close study of the conditions satisfied us that such is not the case, and that there is no advantage to be derived from such adjustment, except when the light is intended to be used in one direction only."

This shows us, among other things, how very great a difference of result in candle-power may be obtained with the same apparatus, if a difference occurs in the arrangement of the points; and it also explains why an arc which gives a very high candle-power when measured, may quite fail to exhibit anything like an equal degree of actual illuminating power when put to some practical use.

Thus, in the case just cited, while the candle-power, measured from the front, would be 287, the average for all directions would be only 139, or about one-half as great.

In this connection a certain advantage is found in the use of machines with alternating currents. Here the carbons both burn away alike to pointed ends, and the light is thus much more equally distributed on all sides. (See Fig. 41.)

In most of the machines now in use the current which produces the light is the same which passes around the coils of the stationary magnets, by which the field of force is developed; hence there is the most intimate relation between the machine and the lamp, and any fluctuation in the resistance offered at the latter is at once felt at the machine. To eliminate this source of uncertainty and irregularity, in some experiments which I have lately conducted with various machines, I have employed a simple, substantial holder for the carbons, with means of adjustment from time to time by hand. This requires, of course, the frequent attention of an assistant during the experiments, but it has in many instances enabled me to eliminate all question of the influence of

the lamp on the running of the machine.

In this connection it would be very appropriate to discuss the construction and merits of the various forms of electric lamps, but this subject I must defer for the present on account of lack of time to arrange the great mass of material here presenting itself, and leave this to be taken up in a subsequent report.

Among the various machines which have been above described, those which have been submitted to trial by your committee during the last year are the following:

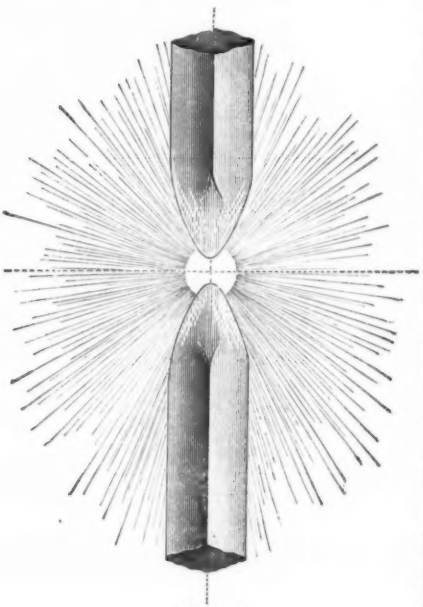


Fig. 41.

The Siemens machine, of the form shown in Fig. 24.

The Wallace-Farmer machine.

The Brush machine.

The Arnoux and Hochhausen machine.

The Weston machine.

The Maxim machine.

Preliminary trials having indicated that the Wallace-Farmer and the Arnoux and Hochhausen machines did not promise to afford results suitable for the purposes contemplated in this examination, they were withdrawn from further test and the work was continued on the other machines alone.

Of these, two machines, each of the Brush, Weston, and Maxim types, were thoroughly tested, so that, in all, seven machines have been tested by your committee in a very thorough manner, involving a very considerable expenditure of time. As this has been taken from days already overcrowded with other duties, but little opportunity has been left for such a thorough scientific discussion of the whole subject involved as I should have wished to give, and I have been obliged to avail myself of such material as I could utilize in the illustration of the subject. The first and all-important object was to find which, among the various machines readily attainable, was best fitted for use in the Light House Department, and all other considerations were of necessity postponed to this.

Having this in view, I confined my tests essentially to the measurement of the light actually obtained from the electric lamp, and to the power actually expended in running the machine.

For determining the former, I employed a Sugg photometer of the usual form employed in measuring the candle-power of ordinary illuminating gas.

This apparatus was inclosed in a temporary dark-room, built of wooden frames, covered with black oil-cloth, which was placed at one end of the physical laboratory of the Stevens Institute of Technology. In this dark room the photometer was so set as to have its candle end towards the distant side of the room, where the electric lamp was arranged opposite a door opening into a dark passage-way of considerable width beyond, thus securing a non-reflecting background to the electric light when desired.

In testing a light, at first the apparatus was employed in the usual way with a pair of standard candles as the standard light; afterwards a Sugg standard burner of 15 holes at the further end of the photometer was standardized with a pair of weighed candles, and this burner was then used as the standard for comparison with the electric light. At the same time the power employed in driving the machine was taken by the use of a transmitting dynamometer,

designed by Mr. William Kent, a graduate of the Institute, and built in the workshops of the Institute by the graduating class of 1879. This is, in fact, a modification of the dynamometer invented by Mr. Samuel Batchelder, of Boston, nearly forty years ago, a description of which may be found in the Journal of the Franklin Institute, 1843, vol. xxxii, p. 277, and in the Scientific American of August 31, 1878. The modification consists in providing a method of making an automatic record, and of indicating more minute variations of the power transmitted. The accompanying cut, Fig. 42, represents the dynamometer without the recording attachment and as it was used in the experiments. The construction of this apparatus and its mode of operation are as follows:

It consists, as shown, of two stout cast-iron frames, held together by bolts in bearings, in the top of which frames run two shafts, each carrying a pulley at its outer end and a bevel-gear wheel of 45° at its inner end. One of these shafts is the driving-shaft, connected by

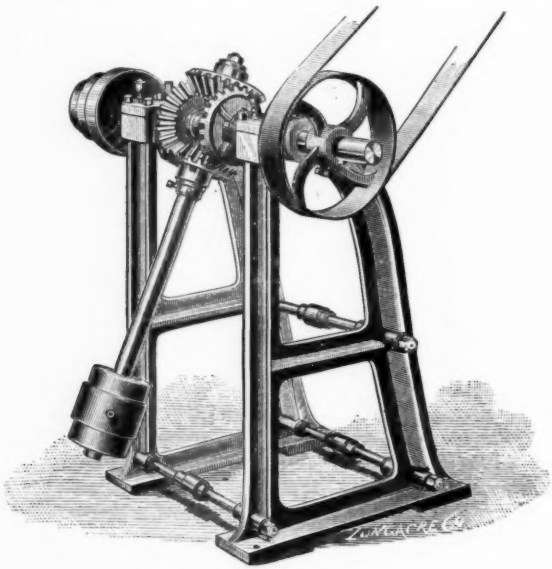


Fig. 42.

belt to the engine or other prime mover; the other is the driven shaft, connected by belt to the machine driven. The power is transmitted from one shaft to the other through two other bevel-wheels of 45° gearing with the first, the shaft common to them and on which they run freely being at right angles to the axis of the two shafts first mentioned, and carrying at one extremity a heavy pendulum.

The bevel-wheels being connected, as shown, and the power being applied to the driving-wheel, the two intermediate wheels with their common shaft have a tendency to revolve around the driving-axis, which tendency is a measure of the force transmitted, and is resisted by the moment of the weight of the pendulum. In the Batchelder dynamometer the four bevel-wheels and their shafts are used, but the shaft connecting the intermediate wheels is always held in a horizontal position, and its tendency to revolve is resisted by weights and a sliding poise applied to an extension of one end of it, which is graduated like a scale-beam. In using the Batchelder dynamometer the operator requires to keep the beam constantly balanced, by shifting the poise on the scale-beam or the weights in the scale-pan hung at its outer end, to

correspond with the variations of the power transmitted, and a record of the power is obtained by noting the weight on the scale-beam at each instant, and the corresponding number of revolutions of the driving-shaft. The horse-power is obtained by multiplying weight in pounds of weighting poise on the scale-beam by the distance in feet of its point of suspension from the driving axis, by the number of revolutions per minute, by 3.1416, and dividing by 33,000.

In the improved dynamometer the horizontal scale-beam with its weights and sliding poise has been dispensed with, and the swinging pendulum substituted.* The tendency of the shaft carrying the two intermediate bevel-wheels, the prolongation of which shaft is the pendulum arm, to revolve around the driving-axis, is measured by the weight of the pendulum and its arm multiplied by the distance of their center of gravity from the driving-axis and by the sine of the angle which the pendulum arm makes with the vertical. When the pendulum hangs in a vertical position the force transmitted is zero, errors due to friction excepted, and when it is horizontal, the sine of the angle being equal to unity, the force is the maximum the apparatus is capable of recording. The weight of pendulum and its position on the arm being constant, the only variables to be considered in measuring the horse-power transmitted are the number of revolutions per minute and the sine of the angle of the inclination of the arm. These variables may be caused to automatically record themselves on a sheet of cross-section paper by any one of a number of devices.

The dynamometer used in these experiments has a capacity for measuring 20 horse-power; a method is provided of measuring very small powers, which consists in lessening the moment of the pendulum and arm, first by shifting the sliding weight nearer the driving-axis; second, if still lighter moment is desired, by removing the weight from the arm entirely; or, third, if even still greater delicacy is desired, by counterbalancing the weight of the arm by adding weight to its upper end, above the upper intermediate bevel-wheel.

During the experiments one person attended to the running of the engine, dynamometer, and machine, while another recorded the number of revolutions of the dynamometer and the inclination of the weighted pendulum; the latter was read from a graduated arc fastened to the pendulum in such a manner as to be in the same plane with its axis; this arc, by the deflection of the pendulum, swung by a pointer attached to a cross-bolt at back of machine, and thus indicated the degrees of inclination of the pendulum. The friction of the dynamometer was obtained by loading its delivery shaft with a weight which produced the same pressure on the bearings as was brought on them when it was transmitting power to the light machines, and then noting the deflection of the pendulum to overcome the friction produced.

In the earlier experiments the readings of the dynamometer were recorded every fifteen minutes and in the later ones every five minutes.

Photometric measurements were also made simultaneously with the reading of the dynamometer, and occasionally one or two between successive readings of the dynamometer.

The tests of machines and lamps for producing the electric light herewith reported, may be divided into two principal groups.* The first group consists of those in a certain sense preliminary, which were made at first to test various general questions, such as the effect of a displacement of the carbons out of a vertical line, the different amount of light given out in different directions under this condition, and the like. In these tests the standard of light employed was a pair of standard candles. In these experiments less frequent readings of the dynamometer were taken, and the results are not regarded as so closely accurate as those obtained in the second series, where a standard 15-hole Sugg burner was used as the light-unit of comparison, and where the dynamometer and photometer readings were taken simultaneously.

* The tables here referred to, twenty-six in number, giving the details of the experiments with different machines, are omitted.

It was deemed sufficient for the purposes of this article to exhibit Table No. 27 of the Report, and to state that the results given represent the averages of several trials of each of the machines—eleven of the Brush Machines, eleven of the Weston, three of the Maxim, and two of the Siemens; the experiments, in many cases, having been continued for a number of hours consecutively.—[Ed.]

TABLE OF AVERAGES.

Machine.	Lamp.	Average can lle-power.	Average hor.e-power.	Average candle-power per horse-power.
Maxim (ordinary type)	Maxim	3,297	5.483	729
Maxim	Hand-lamp	3,930	5.585	704
Siemens	Siemens	4.651	4.863	956
Siemens	Maxim	4,548	4.742	959
Weston	Hand-lamp	8,585	4.769	1,800
Weston	Maxim	7,787	4.683	1,663
Weston	Siemens	7,262	5.056	1,436
Weston	Weston	6,063	4.552	1.332
Maxim (with magnets of low resistance)	Maxim	7,524	7.400	1,017
Brush	Brush	4,365	2.8467*	1,533
Brush	Siemens	3,532	2.9573	1,194

HOW SHALL AN AMERICAN MAN-OF-WAR BE BUILT?

Written for VAN NOSTRAND'S MAGAZINE.

By C. A. E.

THIS question will soon present itself to us for solution. We cannot go on much longer with the few old ships to which we are now reduced. We have waited long enough besides for European experience. A score or so of staunch, serviceable, sea-going boats we must possess. We have to maintain squadrons of a few ships each in the different seas to protect our private and national interests, especially in the neighborhood of those countries loosely governed and in a chronic state of revolution, which at frequent intervals are found violating not only principles of international law but the very dictates of humanity. As a school, too, where to train a reliable and sufficient number of officers and seamen for cases of need, a moderate navy is indispensable. It is a well-known fact that in our naval wars we have been sadly in lack of good American seamen; and had we not been more fortunate with regard to officers, we should have fared badly indeed. Although by tradition and sentiment a pacific people, eager to uphold, through moral influence, international law, and to enlarge the sphere of its operations, yet we should always have back of us *some* physical force, if we would command proper respect among nations armed to the teeth, and valuing highly the possession of ready power. We are certainly not going to fight when we can arrange amicably the matter in dispute; but experience warrants the assumption that our honor, like that of any other nation, is liable at times to be so grossly outraged as to make the people demand with one voice war—and nothing but war. In this event we must have some navy to begin with, for in all probability the fight will be on the sea.

Descending to technical points we may remark that modern ships of war are, and will be, distinguished for some time to come by having as offensive weapons rams and heavy guns, and as a defence armor-plating of a variety of thicknesses and variously arranged. Rams and plating followed, as a natural consequence, the introduction of iron ships and heavy ordnance, and with these only will they disappear. The methods of making rams most effective, their shapes, their sizes, the thicknesses of plating, its quality and arrangement, are the questions to be studied to-day, and not their abolition. Some prophesy that torpedo

warfare will become so perfected that ships will fight with them instead of with guns; but at an equal pace will protection against them have advanced, and rams and guns will continue as before to settle the battle. The world possesses to-day experience sufficient to prove the great efficacy of ramming. Numerous compartments across a vessel may possibly prevent her from sinking when rammed into once, but the second or third time she will, in all probability, go to the bottom. She will be more or less disabled at the first blow, and completely so if she receives it where her engines are, or where some other important part of her mechanism is, located. A ship which is designed essentially as a ram may have every one of her guns knocked to pieces, her crew two-thirds killed and wounded, her deck swept by a terrible fire, her hull above and even at the water-line pierced in many places, but, provided her engines are well protected and remain uninjured, she may be yet made to sink her adversary if she is well handled, and is superior to the latter in speed and evolution. Until her engines are destroyed, she has lost the smaller part of her aggressive character.

Without sacrificing advantages, armor cannot be placed sufficiently thick on a war vessel to prevent an ordinary heavy shot either from going completely through it, if fairly struck at close range, or at least from being shaken out of place. Armor should be thick enough only and so disposed as *to deflect* as often as possible a shot; it should be arranged, in other words, so that it may be very often hit at a pretty acute angle. Where it is really most needed, and should be thickest, is by the engines, especially if they project above or reach near the water line, and for short spaces in front of the guns; all other parts of the ship may have it considerably thinner. The idea which seems so prevalent in Europe of making a war vessel invulnerable nearly everywhere is undoubtedly a wrong one. She is but little less effective in a fight for being riddled at all points except at her engines and guns; the more so if she be arranged inside as to make easy repairs to leaks, and prevent the water from passing from one deck to the other. All, probably, of her mechanism may be kept below the water-line and remain safe. Although over those parts of her hull which must be well protected, comparatively thick armor-plating would appear indispensable, yet at all other points it loads the vessel, and takes away from her efficiency in several very important respects that cannot be sacrificed to invulnerability.

Turrets are objectionable on account of their weight, the limited view from their ports, the really small protection which they afford to the guns, their liability to become jammed when struck very low, the injurious concussions which are experienced inside, the demoralization produced by a shell penetrating and bursting among the gunners. When a ship can well bear the load of a couple of turrets, she would be more formidable if this weight were thrown into several additional guns, and would possess besides better sea-going qualities. So far as the men are concerned, a turret may protect them; but their safety is the least important matter in a fight; those who have fought on vessels prefer to do so in the open, where they are not cramped for room, where they can see more and to greater advantage what is going on. They care nothing for the protection of the turret; on the contrary, they sometimes fear in a turret when they would not outside of it. In the old style of vessel nothing was thought of fighting on an open deck; why should it be different now? Was a four or five inch shot safer to stop then than a nine or eleven inch one is now? As regards the guns, on the other hand, they are almost as liable to be hit projecting out of black port-holes as over a bulwark. A gun itself does not require much, if any, protection; a shot which strikes it is very apt to glance off, especially if it is a large, heavy piece; its carriage, however, demands some protection, although a turret is not necessary for the purpose. Since a monitor carries only one or two very heavy guns, toward which all the fire from a battery may be directed, they need every possible chance of protection. Hence the advisability of turrets for this class of ship. The guns of a sand fort project slightly only above earth-work, and are worked to great advantage against vessels; those of ships, if

mounted in the same way over the bulwarks, would be equally efficient against either floating or stationary batteries. We may conclude, therefore, that apparently a sea-going man-of-war, of a number of guns, needs no turrets or other covered protection; the omission of which does not increase in an important degree the chances of having her armament disabled.

Let us pass next to the third peculiarity of modern warfare; heavy guns. The delicate monsters which are at present the rage in Europe, are pure extravagances. A war vessel should undoubtedly carry a few heavy guns of as high penetrating power as is consistent with the size of ship, the durability of the guns, their reliability, fast firing and easy handling; and those which throw projectiles weighing two hundred or three hundred pounds fulfill well the foregoing conditions. They certainly are amply heavy for the style of vessel we have in view. In fighting another, a ship should use as often as she can her heavy guns; in order to produce as much effect as possible on her opponent's armor; when she is obliged to attack a fortification, she should bring to bear on it as many guns as she can, because the number of shots she can throw into it more than their size, renders her formidable under these circumstances. Consequently she ought to carry, besides her heavy guns, a pretty good battery of others about one-half as powerful. Even when attacking a floating adversary such a battery may produce important effects. As an open deck vessel, which is the kind we are considering, in approaching close to an antagonist may have her deck swept by the latter's Gatling guns, she must carry herself, in the third place, a good number of the same guns favorably located, to reply to this kind of fire.

It is very improbable that an American man-of-war will ever be built in imitation of the monstrosities of Europe. They are too costly to construct and maintain, and besides are too large and of too deep draught to suit our needs and purposes. They are not good sea boats; for which reason they are disliked by naval men all over the world. So enormous is their weight that they do not ride well in the water, in spite of their great beam, and do not sometimes obey satisfactorily the helm. They consume an enormous amount of coal. They are too slow. Speeds of thirteen and fourteen knots per hour, in quiet water, have been assigned to them; but it is doubtful whether the fastest heavy iron-clad afloat steams at sea, under impartial circumstances, ten knots regularly per hour. Some five or six hundred men at least are *inclosed* in them, and should one of them happen to be blown up with a torpedo, or rammed down by another vessel, the sudden loss of life is terrible to contemplate; and must produce a great demoralizing effect in a fleet. Everything connected with them is on such a large scale that, considerable steam or hydraulic power has to be invoked for almost every operation. They are consequently filled with machinery, which very like may be injured or get out of order somewhere in a critical moment, and disable the ship in an important particular. The repairs to this machinery are expensive and of constant recurrence. A fighting vessel, on the contrary, should have as little machinery in her as possible, and that in great part, if not in whole, below the water line, grouped closely together, very accessible, and well protected at exposed points. Every operation that may be effected with manual labor and skill, should be so effected; for on a man-of-war these agents are not wanting.

Keeping in mind the fact that, our navy will be always small, the vessels composing it should be distinguished for speed; in order to derive the utmost service from them in cases of need. On the declaration of a war they may be scattered all over the world, and until we are properly equipped, may be required close at home; therefore they should be able to reach our shores in the shortest time. Once here they have to guard an extensive line of sea coast, and should be able to fly to any point suddenly threatened. On the sea they may have to chase fast merchantmen and faster privateers of the enemy. Performing blockade duty, again, their speed is of greater consequence than any other quality. If one of them should happen to be pursued by one or several men-of-war of the enemy, she

ought to be able to save herself from fighting against disadvantageous odds. If, in her turn, she is chasing another vessel, she ought to come up to her as soon as possible, and with her ram principally decide the contest. To render herself formidable as a ram, however, she must be swift; her blow will then be given with more than ordinary effect, and should she miss her opponent the first time, she will sweep past her quickly and return as quickly to the charge, exposing herself a short time only to fire. Her good speed will favor her also in not permitting her opponent to get out of her way.

She will require to be driven with twin screws, moved by two powerful engines. All the room necessary for the proper arrangement of her engines, the number of her boilers, and the size of her coal bunkers, should be taken, even if she remain cramped for space in other particulars. As her crew all told will reach somewhere between 250 and 300 men, and her guns large and small will number from 12 to 14, her length, to enable her to sustain regularly a good speed with moderate consumption of coal, must be about 270 or 280 feet. Her speed should be 13 knots per hour, when the ship is uninfluenced by wind or current; and by forcing her engines and boilers, and consuming about 30 per cent. more coal, between one and two more knots per hour should be got out of her. In fact, to keep down her cost, to render her quick in evolution, and easily handled in our rivers, her length cannot well exceed the limit indicated of 280 feet. Her maximum draught should not pass beyond 18 feet, if she is to go easily over the bars at the mouths of most large streams, and penetrate well up into them; and also navigate if necessary along our coast in depths unsuitable for other war vessels of greater draught. The foregoing moderate draught possesses this advantage too; she can approach close to shore toward a fortified point which she intends to attack. Smaller than 18 feet her draught cannot well be made, considering the load of armament, armor, coal and engines which she will have to carry. Still, if it could be reduced to 16 feet, her efficiency as a ram and as a cruiser along our coast, would be considerably augmented. In order that she may set in the water with stability, and present a steady deck with necessary room below, her greatest width of beam, measured at the water line, should be some 45 or 46 feet. A greater width would interfere with her having suitable lines for her speed, and a lesser one would not give her enough deck room, as well as buoyancy. An armored vessel carrying heavy artillery, large amounts of coal and ammunition, many boilers and heavy engines, cannot have the fine lines of a race boat, without sacrificing in her considerable buoyancy and stability; although her armor and artillery be reduced so as to become comparatively light. Her bow and stern may be designed moderately sharp; this feature will not prevent her maximum width from being carried some considerable distance along her sides before it is materially diminished. Stability and diminution of draught are secured at the same time by means of full sections and a rather flat bottom amidships. We may reasonably count upon her extra strong engines counterbalancing to a certain extent want of fineness in her lines; but her extreme breadth cannot be greater than one-sixth of her length, and her maximum draught more than 18 feet, without taxing too much her engines.

She should lie as much as possible under water, which element is the best protection she can have against the shot of an enemy. Therefore her deck, when she has everything aboard, should not rise more than 4 feet above her line of floatation. If circumstances permit it she ought to sink herself a foot lower still with water when she prepares for action. She will expose in all cases only a narrow strip of her hull to fire; and, being of moderate draught, considerable beam, and not great weight, she will be able to ride easily a heavy sea, and keep her deck quite dry in bad weather. As she is nevertheless exposed to ship heavy seas, plenty of outlets well protected are required in her sides to let the water escape quickly. She will possess a steadier deck, and require much less armor plating than if she rose 7 or 8 feet out of water; the former is a matter of some importance as regards accurate firing from a vessel. A low broad-side, with no houses on deck, make a ship

present small surface to the wind, and gives her better sea-going qualities, as well as subjects her to less retardation in her speed under adverse circumstances of wind and waves. Her bulwarks are not to be pierced with any port-holes; they are to rise some 4 feet above her deck; her guns will fire over her bulwarks and be elevated therefore between 8 and 9 feet above the water. Although this height is not sufficient generally for long range firing, yet an advantage of this nature may well be sacrificed in this instance, considering that she is a vessel intended to fight at close quarters.

Commencing at about a foot below her highest water-line, her sides should run up perfectly straight to the top of her bulwarks, falling inward from the vertical some 30° or 32°; which inclination is to be carried along both boards of the ship to within a proper distance of her ends, when it should begin to diminish gradually until her sides become perfectly vertical at her bow and stern. No material interference evidently will occur with her lines below her plane of floatation; and they may be designed the same as though her sides were of the usual shape. Her buoyancy, however, will be increased at her ends with nearly vertical sides there running for some distance back.

Opposite to her engines her armor may be 5 inches thick; over other parts of her hull it may descend to 4, except for some 25 or 30 feet along her bows and stern, where it may be only 3 inches. It should not pass above her deck, except where her guns are located; at which points it may reach to the top of her bulwarks, extend for a few feet on each side of the guns, in order to protect their carriages, and have its thickness augmented an inch or so. Thus arranged the chances for shots which strike her sides below the deck glancing off are greatly increased. By swinging over her sides her chain cables as armor when she goes into action, she is still in better trim for defending herself by deflecting shots. Some deck-room will have to be sacrificed to the foregoing disposition of her sides, and some head-room below also; but these disadvantages are not great. Her armor and guns, on the other hand, will be put nearer the center of the ship, and she will have more stability in the water, with a steadier deck from which to fire. The bulwarks should be thick enough to prevent the bullets of Gatling guns from going through them. At some 30 or 35 feet from the end of the bows, inclined armored defences 4 feet high, should be run obliquely across the deck from both bulwarks, to meet in its center. In the angular space so formed should be put one, or better, two heavy guns, the carriages of which will be protected by armor plating on the defences in front, and on the bulwarks at the sides. The same arrangement should be introduced at the other end of the ship. Forward of the bow guns the bulwarks should rise about 6 feet above the deck, and be made removable; so that when the vessel goes into action, these guns won't blow them away and tear up the deck ahead. At the stern similar bulwarks are needed, but not rising so high by 2 feet. A battery of 8 or 10 comparatively small guns should be carried along her broadsides. Around her masts, and on light open-work bridges reaching across the deck at an elevation of 12 feet, and, supported at their center and ends, should be placed a dozen or more Gatling guns.

Several advantages are connected with putting her heavy guns at her bow and stern. In whatever position relatively to herself lies the enemy, she can always bring at least half of these guns to bear on him, and when chased also she can utilize them. When, on the contrary, she assumes the aggressive, being essentially a ram, she will approach close to her adversary, and fight with her bows toward him; in order to ram at the first favorable opportunity, while she is using in the meantime her most effective guns on him. Her broadsides are her weak spots; these she should expose as little as possible to a floating enemy; but her bows and stern, if only moderately sharp, will be well shaped for deflecting shots. However, to prevent the possibility of a very heavy shot entering her bows below the deck and passing nearly or entirely through her hull lengthwise, a couple of bulk heads a certain distance apart, inclined, covered each from about the water line to under the deck with 3 or 4 inches of plating, and located under

her bow guns, may prove efficacious. In fighting a fortification, or shore battery, she will present her broadsides, and run the risk, perhaps, of having a heavy shot sent into her engine room; but she is none the less able to continue fighting if her guns are not dismounted, and she does not make water at every point.

Her deck should be level from stem to stern, and properly shaped in plan fore and aft; where it should present width enough for her heavy guns. It should be capable of being made tight over all openings, and should be encumbered as little as possible with projections. Light and air will have to pass down through apertures in it. In time of peace a man-of-war is made to proceed as much as possible under sail, consequently heavy rigging is usually carried; but in case of war, a vessel, such as we have described, should have her rigging changed, and diminished to the minimum amount, as she will then steam entirely, and will not want to have her deck encumbered during an action with the debris of rigging. Her deck lying low, she will not, under any circumstances, be able to carry much sail; in fact, she is designed as a steamer, pure and simple, availing herself slightly only of wind power, but amply provided with coal space.

A NEW METHOD OF DECENTRING.

By M. HENRY.

Translated from "Annales des Ponts et Chaussées" for VAN NOSTRAND'S MAGAZINE.

THE system of decentring by means of rollers has for its object the substitution of rolling friction in place of the sliding friction of the wedges or ratchets which are sometimes employed in decentering arches; and, furthermore, to employ a method which may be used in the water.

The following illustrations will suffice to give a complete description of the construction and method of working of the apparatus employed:

Fig. 1.

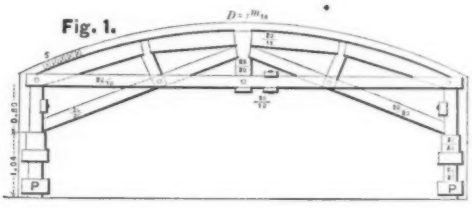
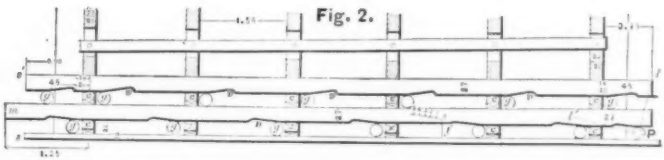


Fig. 2.



Between the lower sill s and the upper one s' of the center, and on each side of the arch are placed two series of rollers g, g, g . . . . . separated each from the other by a key or movable block m, which can be moved in a direction lengthwise of the arch, and confines the rollers in their inclined notches v, v, v.....

The wedges c, c, c, placed between the sills are designed to relieve the rollers and to afford increased stability to the system during construction.

Two levers working over the rollers P, P, P, placed at the head of the arch at

one end of one of the series of rollers, serve to overcome the resistance to starting, and to facilitate the movement or to retard it as the case may be during its course.

Marks *f f*, upon the lower sill corresponding to similar marks numbered

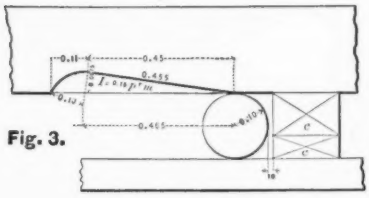


Fig. 3.

upon each of the movable sills, serve to indicate the progress of decentring.

The radius of the rollers being $0^m.10$, and the slope of the notches in which they roll being $0^m.15$ per meter, it is seen that three quarters of a revolution (or even a little less than this) of the rollers leads to a lowering of $0.0675 \times 2 = 0.135$. The drop of the center would evidently be $0.0675 \times 3 = 0.2025$ if the notches of the same form and arrangement were in the lower sill.

In case the levers were insufficient to start the centering, or, what is the same thing, in case the resistance to rolling friction of the four series of ordinary rollers is greater than the resistance to the sliding of the two traveling rollers, recourse must be had to jacks. The levers would then be employed to continue the motion started by the jacks, and to regulate the movement of the rollers.

This system of decentring was first employed in 1875 by M. Chadard, engineer in charge of the highways of the *arrondisement* of Clamecy.

We had the honor of introducing the plan to his notice, on the occasion of building an oblique bridge under his direction across the river Chalaux, near Lormes.

The rise of the arch was $2^m.65$ under the keystone. The span was 6 meters and the angle of skew 60°. The decentring was accomplished in the water.

The following extract is from a letter from M. Chadard to M. Chatoney, inspector of bridges and highways:

"I would advise the adoption of very low inclinations for the slopes of the sills which enclose a series of rollers. At Chalaux this inclination was too great, and with a very slight effort the decentring proceeded much too rapidly. The question must be decided by experiment, for I must confess that the conclusions derived from my calculations were not verified. It is reasonable to suppose that the inclination in question should vary in some way with the weight of the framing, or better perhaps that the notch should present a curved form approaching the cycloid, instead of an inclined plane. Be that as it may, however, notwithstanding the difficulties of a first trial, I have good reason to be satisfied with my experience, and I am convinced that under conditions analogous to those I encountered, the system of rollers is capable of rendering good service."

Steel Plates for American War-Ships.—A Washington special says:—"Several members of the House Naval Committee have been considering the question of the substitution of steel for iron in the construction of armored ships of war. Having obtained considerable information on this subject, they are desirous of getting this before the full committee, and at their next meeting the matter will be formally brought up and considered. Mr. McKay, a ship builder, and others from Boston and New York, will appear, and submit to the committee the results of the experiments in England and Germany, showing that the maritime Powers of Europe have abandoned the use of iron for armor plates, substituting steel, as it is found by actual test that five inches of compound steel plate will afford a resistance equal to ten inches of iron. It has been suggested to the committee that the subject had better be thoroughly examined before reporting the appropriation asked by the Secretary of the Navy for the completion of the four "iron-clads" authorized by Act of Congress. The Secretary of the Navy is also considering this matter, and expects shortly to forward to the committee the result of his investigations.—*Iron.*

RAILROAD SIGNALS.*

BLOCK AND INTERLOCKING SYSTEM.

THERE can be no doubt that, for security from rear collisions, and from accidents occurring by reason of misplaced switches, or open draw-bridges, the block system, carried out by interlocking switches and signals, comes nearer to insuring immunity from accident, than any other known device. The block system, long used in England, and now brought almost to perfection by interlocking devices, is so called because under it each section of road is "blocked" by signals against the entrance of a train, while that section is occupied by another train. Improving on the former system, which only provided for an interval of time between successive trains, the block system secured an interval of space. Under it a railroad was divided into telegraphic sections. Before a train could start from the first station, a signal was sent from the first to the second, and a favorable reply was received; then a signal was made for the train to leave station one, and at the same time station two was notified of the fact; this notification was acknowledged, and the section was "blocked" by a signal showing that it was occupied. When the train reached station two, a signal was sent to station one that the line was clear, and the "block" was taken off. Of course, if the train met with an accident, or if it was delayed in reaching the second station, the section continued to be blocked; and no other train entered it until a signal from the second station gave notice that the danger had ceased. And the same precautions guarded every section throughout the line.

THE INTERLOCKING OF SWITCHES AND SIGNALS,

combined with the block system, not only secures each section from the entrance of a train while it is already occupied, but also blocks the section for any train while the track is broken by the throwing of a switch, or by the opening of a drawbridge, thus removing these causes of numerous disasters, while it allows a vast increase in the number of trains.

The method in brief, is by the use of levers operating switches and signals so interlocked that a signal of safety cannot be given while danger exists, and danger cannot exist until after it has been signaled. In other words, the operator cannot, by negligence or forgetfulness, or even from malice, create a danger, or suffer it to exist, until he has signaled it afar off, to any approaching train. He cannot open a switch before setting a signal at danger; having opened a switch, he cannot leave a signal at safety; he cannot set the signal at safety before closing the switch; he cannot leave the switch half closed without giving a signal of danger. All these four errors, each of which has cost many lives, are made impossible in a section of road guarded by this system. And the boast is not extravagant, that for this purpose, the working of signals is not trusted to the intelligence, or to the fidelity of a man, but that each man becomes part of an unerring machine, in which his will ceases to operate, and he must act in accordance with the principles of its mechanism.

Mr. Barry, in his work on railway appliances, gives a strong illustration of the perfection to which mechanical provisions for safety have been carried. At Cannon-street station in London, seventy switch and signal levers are placed in one signal house, making millions of combinations possible, if they were not interlocked. Of these combinations only eight hundred and eight are safe. Yet a stranger, blindfolded or blind, handling these levers at random, cannot produce a condition of danger. He could stop trains and hinder business, but he could not create a possibility of danger without signaling it in advance.

More than this—because the pulling of the wrong levers, although not causing immediate accidents, does strain the machine, and thus might lead to unlocking of the levers, with consequent disaster; therefore, the attempt and bare

* Abstract from the Eleventh Annual Report of the Railroad Commissioners of Massachusetts.

idea of pulling the wrong lever is checked by mechanical means, and the uncertain will of man is subordinated to the perfect mechanism of this device.

In operating this apparatus two systems of signals are used, one near the cabin or tower of the operator, and one at a distance sufficient to enable a train to be stopped after the signal is seen, and before entering on the blocked section. The semaphore is used by day for a signal, as being the one distinguishable at a greater distance than any other form. At night, colored lights are used. Mechanical means may be employed for short distances; electricity serves for long distances. To supplement the signal, if it should be obscured by fog or darkness, a "contact bar" is sometimes used, which, with the danger signal, assumes a horizontal position, and by striking the cab of the locomotive gives a warning somewhat like that given by the bridge-guards which strike the person who is exposed on a freight car.

The working of this system for drawbridges is the same as for switches. The draw cannot be opened until the signal for danger has been set. The signal of safety cannot be given until the draw has been closed and actually locked.

By uniting the interlocking device with the block system it becomes impossible to telegraph safety from one signal station to the station next in the rear, until all the switches are in a safe position for a coming train. It is impossible to move switches so as to allow access from a siding to a track which has been telegraphed as safe for a coming train. It is impossible to so move the switches, or any one of them, after the line has been telegraphed to be blocked. It is impossible for a train to enter a section until its coming has been announced by telegraph, for the signal to enter cannot be given until a signal announcing its approach has been received. The signal which permits entrance into a section cannot be given without the concurrence of signal-men at both ends of the section. The starting signal is reset at danger by machinery behind every train. The signal that the line is blocked must be given from the station in advance to the station in the rear.

This summary, in substance, is borrowed from a description of the combination of the Toucey and Buchanan with the Saxby and Farmer devices, which, aided by some subsidiary inventions, are now in use on a portion of the Pennsylvania Railroad, and on the Metropolitan Elevated Railroad in New York, as well as elsewhere.

The ingenious device of David Rousseau, involving the same principles, and accomplishing the same end, may be seen at the New York Grand Central Depot. The members of the Board have seen the operation of these inventions at these points; and their daily working vindicates the high claim made on their behalf. It will be a happy day for travelers when this system, in all its completeness, has been universally adopted on American railroads.

But the block system, as operated with interlocking devices in England and France, and as used with additional improvements on portions of American roads, requires a large body of skilled and well-paid men. For an unskilled operator, although he could not cause danger, would cause delay and difficulty. Our inventors, therefore, have tried to supply its place by automatic signals, guarding a road and giving warning of danger, without the constant intervention of man. And it is claimed by some of them that their inventions are not only more economical than the English system, but that they are safer. In the language of one of these inventors: "My device is better than a man, for it is always on hand; it never sleeps, and it never drinks."

As a preliminary remark to a discussion of automatic signals, it may be observed that it is a requisite of any system that the normal condition of its signals should indicate danger, so that in case of any derangement of apparatus, accidental or intentional, warning will be given. Thus, failure to act will at most stop or check the movement of a train. It will never cause a disaster. A device that fails in this particular, fails at the outset. It is, also, absolutely requisite that the danger signal should be given far in advance of the point of danger. A signal displayed at or near

the point of danger is utterly insufficient and unsatisfactory.

HALL'S ELECTRIC SIGNAL

is the best known and most widely used. He employs an open circuit; and the current which keeps his signals set at safety is transmitted over wires. This current being broken by an engine entering a section and touching a circuit closer, sets the signal at danger.

1. As a safeguard from rear collision, theoretically at least, it approaches perfection. The danger signals are set a mile or less apart, and a red disk shows that a section is occupied. A secondary signal, sometimes called a tell-tale, is placed a thousand feet in advance of the danger signal, and informs the engineer whether the danger signal behind him has been set. When the engine passes out of a section, it sets the signal of safety for that section. If the current ceases to work from any cause, a signal of danger will be given. But absolute perfection has not yet been obtained in the construction of the apparatus; and the passage of a train sometimes fails to set the signal of danger; yet, in that case, the tell-tale will indicate danger. And so it cannot happen that both signals belonging to a pair will indicate safety when danger ought to be announced.

2. Station agents, by a separate device, can arrest the progress of a train at a distance of half a mile by a signal of danger.

3. The connection of switches with this system makes it impossible to open a switch so connected without blocking the track by a signal. This occurs at a distance of two thousand feet, more or less; and at the same time a bell rings at the switch, and continues to ring until the switch is closed.

4. The application of this system to draw-bridges appears to secure perfect safety. It is impossible to open a draw-bridge without blocking the track by a distant signal; and if the engineer fails to see, or recklessly disregards the blocking signal, then another signal will arrest his progress—a mechanical drop constructed of heavy plank, placed two thousand feet from the draw, and so arranged that it falls by gravity when the draw is opened; and if the engineer still presses on, his locomotive is sure to lose its smoke-stack, and he yet has time to check his train and escape disaster. The working of this device was curiously illustrated when it was first used on a road in New York; for the train-men, having a prejudice against it, as a novelty, determined to disregard it; and more than one engineer bringing in his locomotive without a smoke-stack, gave the best evidence of his own recklessness and of the merits of the invention. Now, that draw is opened one hundred and thirty times a day, and it is approached without fear of accident. Two other adjuncts furnish additional safeguards in approaching a draw-bridge guarded by Hall's signals—a bell ringing at a distance of a mile when the draw-bridge is opened, and a signal given to the bridge-tender if the train enters the blocked section.

5. The notice given to passengers and agents at stations, by bells differing in tone for "up" and "down" trains, announcing the approach of a train is convenient, and tends to prevent accidents. For its purpose it is a perfect device, while it saves the great annoyance of whistling.

6. Highway crossings at grade are guarded by a bell, or gong, placed at the crossing, which begins to ring when a train approaches within half a mile, and continues to sound until the train has passed. This calls the attention of the flagman or gatekeeper to his duty. And if the sound were loud enough, it would arrest the attention of travelers, and warn them of the coming danger. Some device of this kind has been heretofore urged by this Board; and their views are repeated in their report on the Lincoln accident. With such an appliance, giving an alarm sufficient to command attention and always in working order, there would be absolutely no excuse for an accident at a crossing, unless it happended to a man blind as well as deaf; for not only does the bell sound, but a signal to stop is displayed to the eye automatically while the danger continues.

But such a device, in order to be depended upon, must be without the possibility of failure; and neither in theory nor in practice can this be said of Mr. Hall's crossing signal. The ringing is

done by the positive aetion of electricity put in operation by the passing of a train. If the apparatus is out of order no current is produced and no warning is given. The principle that danger should be indicated unless something positive happens to prevent it, is not carried out in this part of Mr. Hall's invention. And, in fact, we learn that such an apparatus, placed within the limits of Boston, does occasionally fail to announce a coming train. Its use, therefore, is only auxiliary; and it will not, as it now exists, allow railroad managers to dispense with other safeguards at highway crossings.

The objections urged against Mr. Hall's block or track and switch signals, apart from their cost, are mainly these:

(1.) It is said that they are so delicate and complicated, that they often fail. This, to be sure, when the failure is of electric current, does not directly result in an accident. It only delays a train. Each double-track road has orders directing the time of delay on seeing the signal of danger; a time necessarily brief—say one minute—and after this the train proceeds "with caution." But the tendency of frequent false alarms is to reduce the amount of caution; and the cry of "wolf," too often repeated, may make it unavailing when danger really comes.

(2.) It gives no warning of a broken rail, and does not profess to give such warning.

(3.) Neither does it give warning of a car left on the track by a passing train —an accident not unusual, especially with freight trains. On the contrary, in such a case, the engine with the portion of a train attached to it, passing off from the obstructed section, sets the signal of safety, and lures a coming train into danger by a false announcement. Something like this happened recently on one of our Massachusetts roads. An engine was sent after dark to take five cars from a siding, push them on the main track, and then haul them away. There proved to be six cars which were pushed from the siding, and when the five were hauled away, one uncoupled car remained on the main track. A passenger train afterwards left the station and came in collision with this car. Fortunately, the result was not serious, but it illustrates a danger against which Mr. Hall's signals do not profess to guard.

(4.) So it is said that a train on a guarded section, followed by another train proceeding with caution, would, on passing off, set the signal of safety. The second train breaking down, from some defect of wheel or like cause, would remain as an obstacle and possible cause of collision with a third train coming on the section with the assurance of a clear track given by the signal. This, however, could never occur unless the second train were allowed to enter a blocked section, nor without gross carelessness on the part of those in charge of that train in neglecting to flag the section.

THE UNION ELECTRIC SIGNAL,

hitherto little tried in actual working, professes to do away with all these objections, and to guard against all the dangers which Mr. Hall leaves unguarded. Its fundamental difference from his system is, that it uses a closed circuit, with an electric current moving through the rails; and this current holds the signal at safety, from which it is moved to danger by mechanical means, whenever the current is checked, whether by the dangers intended to be guarded against, or by some accident to the apparatus. Thus, in all its operations (as in most of Mr. Hall's) a failure to work gives warning of danger, but no failure can entice a train into peril. The circuit through the rails is made more effective by wires connecting each rail with the next and firmly fastened at every joint. This was found necessary because the oxidization of the rails interrupted their conducting power. Each section is insulated by the use of vulcanized fibre. This seems to be effectual. The mechanical means by which the signal is given, in case of a broken current, is a simple clock weight so arranged that it runs for several days, giving passage for six hundred trains before it runs down. The current is produced by a battery; and in cold weather a kerosene lamp, burning for a week at a time, is used to keep the liquid from freezing.

When a section of road is guarded by this device, the entrance of a locomotive breaks the current simply by placing its

wheels upon the conducting rails; and thereupon visible signals of danger are given, and when the train approaches a station or crossing a warning bell is rung. So excellent is its working, that a piece of wire laid across the rails breaks the current and sets the signal of danger; and a stray goat, dragging his chain after him across the track of the Providence Railroad recently, gave the alarm as of a coming train to the gate man at Forest Hills crossing. A secondary, or tell-tale signal, in this system informs the engineer at once whether or not his train has given warning. And station agents have the means of warning a train that is entering on a blocked track. This device is considerably cheaper than Mr. Hall's; and it is claimed, that, being simpler, it is less likely to be out of order. But it certainly has these more important advantages:

(1.) As a crossing signal it indicates danger in case of any accident to the apparatus. The failure of a battery, the breaking of the apparatus by accident or design, would of itself give an alarm, while in such case, as has been said, the Hall device would cease to work, and trains would pass without warning. It is claimed, also, that it has this incidental advantage: under it the bell is sounded by mechanical means, which are released by breaking the electrical current. And so the ringing may be done more powerfully than when it was effected by the direct power of electricity, which is variable, and which, as practically used, is supposed to be feebler than the cheap mechanical power applied by clock motion. But the soundness of this claim has not been demonstrated by any exhibition made to this Board. And no crossing signal of this system has yet been exhibited which seems calculated to arrest the traveler's attention, as thoroughly and certainly as it should.

(2.) The breaking or displacement of a rail, by interrupting the current of electricity, gives a signal of danger, provided the displacement of the portions of the rail is sufficient to cause such interruption.

(3.) It indicates the presence of a car on the track by whatever means it came there.

The invention has not been used nearly as much as Mr. Hall's. Its proprietors, therefore, cannot refer to so many witnesses as to its working. Probably it is just to add that, for the same reason, there may have been fewer criticisms on its defects. As has been suggested before, there seems to be this advantage in using a closed circuit, that it requires less from electricity. The labor of this system is done by gravitation, and electric force is only used to control it. Electricians are accustomed to say—"The less you ask of electricity the more sure you are to get what you want." In the present state of science this is no doubt true.

Among the possibilities of failure with this signal, is neglect to wind up the weight, which would prevent any signal from being given. Some also object to the need of lighted lamps in cold weather; but failure of a lamp, resulting in the failure of a battery, would set a signal of danger. On one road, where a few of these signals are used, frequent breaking of the wires is complained of as giving needless signals of danger. The Fitchburg Railroad Company has had the signal on five miles of its road for more than a year, including the whole of last winter. Since May it has been in charge of the officials of the road, and their report is highly favorable. If it works well through the winter, it will have had that full and continued testing which such inventions need before they can be commended with entire confidence.

ROSSEAU'S SAFETY RAILWAY SIGNAL.

This signal has already been referred to as used in blocking the New York Central and Hudson River Railroad, where it has been in successful operation for nearly four years. It resembles Hall's system in many points—among others, in using an open circuit. It resembles the Union Electric Signal in using gravitation as the power which actually gives the signals, thus requiring a less powerful battery than the devices where electricity does the direct work. The signal is set by a clock-weight; and when wound up, it signals three hundred and fifty trains before it needs winding again. By an ingenious device the lamp on these signals cannot be removed for trimming without winding up the weight

As in the inventions described before, the engine, when it enters a section, sets the signal at red, meaning danger, and it so continues until the train has passed off, when it sets it at clear, meaning safety. Each of these effects is produced by a "commutator" over which the wheels pass. In places of extra hazard, two danger signals are used—one called a distance or cautionary signal, a thousand feet in advance of the signal within the section that is to be entered. If this distance signal shows green (or any color selected for the purpose) it indicates that the second signal is red, and that the engineer must stop before entering on that blocked section. This system also provides each station master with the means of stopping any approaching train if danger has been shown to exist; and an indicator keeps him acquainted with every movement on his section of the road. An extra signal, to be used in foggy weather or in dark tunnels, is a rod, which not only strikes the engine, but by an additional device causes the whistle to sound; and it is said it can be applied to the brake, and made to stop the train. The long use of this signal in the Harlem Tunnel is relied on as proof of its excellence. The application of the system to switches and draw-bridges needs no explanation. And the application of all these systems to a single track, while it presents points of difficulty, is a matter of detail which need not be discussed.

BEAN'S ATMOSPHERIC SIGNAL

is a safeguard against the dangers arising from open switches and draw-bridges; and it is also applicable to stations and crossings. The Old Colony Road has tested this device by using it at exposed points for more than two years, gradually increasing the number of instruments in use, and now having them working at distances varying from a thousand to two thousand four hundred feet at one drawbridge, two stations, and several switches. This signal is simple and inexpensive; and, so far as it has been used, and for what it undertakes to accomplish, it seems to be an almost faultness device.

In conclusion, it is evident that the time has not come when the adoption of any one of the devices exhibited for giving automatic signals should be required by law. No party has asked for legislation; and Mr. Hall strongly disclaims any desire for legislative action. Nor, pending further experience on the part of railroad men, and further experiments by electricians and other inventors, can it be thought strange that railroad companies hesitate to equip their roads fully with imperfect devices, which may soon be set aside for better. Many ingenious men are giving their thoughts to railroad signals. The laws of the force, which most of them are trying to use, are not fully known, and the force is not capable of entire control. The railroad managers of England, and, indeed, of Europe, are more than skeptical as to the use of automatic signals, electric or otherwise. They would regard reliance upon such signals as criminal recklessness, if they were not supplemented by other appliances. Many railroad men in this country share this feeling; and this refers not only to railroad managers, who might be suspected of being influenced by undue economy, but to skilled superintendents and other experts who have no such motive. At present no one has the the right to say of any system of signals as a whole: "This is the system that ought to be adopted on all roads." The desire is natural that some tribunal should decide at once which is the best, and that the legislature should order its adoption. But the time for such a decision has not yet come, even if any automatic device can ever be found which will alone answer all the purposes of a railroad safety signal.

Yet it should be remembered that these imperfect devices do render great service in announcing danger and preventing accidents. The worth of a safety signal is to be estimated chiefly, not by counting the number of its false alarms, but by its well-founded alarms. Even an occasional failure to give warning of danger, while it forbids sole and implicit reliance upon an automatic signal, does not prevent its being of great value as an auxiliary. When the terrible consequences of a railroad disaster are considered, a preventable accident becomes a crime. The public have a right to expect that their safety will be guarded by every reasonable precaution, and that devices designed for this end should

not be rejected simply because they have not attained perfection. Railroad managers should be quick to guard their tracks, and especially all draw-bridges and other points of special danger, by those appliances, that seem to them best adapted to insure safety. It is proper to add that our chief railroad companies have shown a praiseworthy spirit, both in testing new inventions, and in adopting those, that, upon trial, have commended themselves to their judgment.

PORTLAND CEMENT.

By HENRY FAIJA, Assoc. M. Inst. C. E.

From "The Building News."

I BELIEVE it is some forty years since Professor Donaldson made some very interesting and exhaustive experiments with Roman cement and with the septaria from which that cement is made. Roman cement was then employed in almost every building of importance, while what is known as Portland cement had scarcely emerged from the laboratory and was practically unknown. The introduction of this then new cement, it is needless to say, was met on all sides with great opposition, but its eminently hydraulic properties and great strength eventually asserted themselves, until at the present time Portland cement is synonymous with strength. But, like all manufactures which assume large proportions, there are unfortunately both good and inferior cements to be met with; and as the strength of a concrete or mortar must depend not only on the quality and properties, size and shape of its aggregates, and the means employed for their amalgamation, but also on the strength and quality of the cement, I propose in this paper to speak solely of the primary source of strength, viz., the cement. The recognized tests for Portland cement, are its weight per striked bushel; the fineness to which it is ground; its color, and its tensile strength. With the exception of the tensile strength, which is an absolute test, these tests are really only problematical, for it is evidently possible to obtain a material that, in weight, color, and fineness, may approximate to the standard required in Portland cement, and yet not be cement. Hence a bad or a damaged cement may possess all these requisite qualities and yet fail in the crucial test of strength. It is also possible, but in a minor degree, to have a cement that is of the required strength, but would yet fail to give the results expected of it, when made into concrete or mortar. From experiments extending over a considerable period, the results of which are given in the accompanying tables, I hope to be able by (1) determining the work which a cement has to do, and (2) by considering separately the properties which it should possess to attain that object, to arrive at such results as will be of value to both users and manufaturers. Concrete or mortar, being a combination of aggregates which are united into a compact mass by means of the cement, it follows:—that the cement should possess strength; that it should be so finely ground as to thoroughly intermingle with and separate all the aggregates used, thus cementitiously uniting each particle; that it should set fairly quickly, and that it should neither expand nor contract during setting. Without describing the manufacture of cement, which is carried out in various ways according to the nature of the raw materials used, it may be considered, for the purposes of this paper, a combination of carbonate of lime, silica, and alumina in certain proportions. These ingredients are obtained in different localities in various forms. Thus, on the Thames, the white chalk, which is nearly a pure carbonate of lime, is used in combination with Medway mud, which contains the silica and alumina. In many works on the Medway the grey chalk is substituted for the white, and Gault clay is used instead of the Medway mud. At Folkstone and other places on the South coast, similar materials are used. At Harwich, Newcastle-on-Tyne and Stockton-on-Tees, a local

blue clay which contains the requisite proportions of silica and alumina is used in combination with chalk, which is imported generally from the Thames. In the North of France—in the neighborhood of Neufchatel and Devres—a natural cement earth is found, generally at the foot of the chalk hills. This material, which much resembles grey chalk in appearance, contains, in many instances, the exact proportions of lime, silica, and alumina for th · production of a high-class cement. At Rugby, in Somersetshire, and other parts of England, the blue lias formation supplies the requisite ingredients, the stone and clay being found in layers of from a few inches to as many feet in thickness, one above the other. At Madras, a cement is made from lime produced from seashells, used in combination with a river mud, and I have lately been consulted respecting the manufacture of cement from somewhat similar materials, viz: coral lime and a river mud, found on the opposite side of India. At Rio de Janeiro also similar raw materials are used. In Derbyshire, the immense limestone hills may be made available for conversion into cement, in combination with a tufa which is also found in the locality. In Buckinghamshire, on an estate on which I am at present engaged, there has been found a deposit of a natural cement-earth, which lies immediately under the surface and averages about 10 ft. in thickness, lying directly on the Oxford clay; with it is intermingled a considerable quantity of a nodular limestone. It would be needless to enter more fully into the geology of Portland cement manufacture, but it may be taken that wherever carbonate of lime, silica, and alumina are met with, in a fairly easy convertible form, there Portland cement can be made. But with each variety of material different means must be employed for attaining the desired end; and to describe the process of manufacture in each case would take up more time than is at our disposal. The process may, however, briefly be divided into three stages, viz:—the thorough mechanical combination of the raw materials, their calcination, and the reduction of the clinker by grinding to the Portland cement of commerce. From this very cursory glance at the materials from which Portland cement can be made and the mode of manufacture, it will readily be seen that there are many causes which may materially affect the result of the cement produced, viz: the quality of the raw materials themselves, their amalgamation in correct proportions, their perfect mechanical combination, the proper calcination of the combination, the perfect reduction of the clinker to a fine powder, and lastly the careful storage and cooling of the cement before it is used. Of the causes of many of the results which may be met with, it is impossible to more than allude to, but assuming that the raw materials have been well chosen, an imperfect amalgamation of them will probably produce a blowing cement. The use of an undue quantity of lime will produce the same result, combined with slow-setting powers, while the use of too much clay will produce a quick-setting cement, that will contract. Having secured the perfect amalgamation of the raw materials in the proper proportions, similar results may be obtained from imperfect calcination, thus a lightly burned cement will be quick-setting, and an overburned cement slow. Having regard, therefore, to the number and combination of circumstances which present themselves for consideration, when it is required to divine the causes which produce certain results, I propose to treat solely with the peculiarities and properties which developed themselves during the experiments made with certain samples of cement, and to deduce from these results certain data which may be of service in judging of the quality of a cement for the purposes for which it is required. The quality usually required of cement is in accordance with the standard set out by the Metropolitan Board of Works in the regulations relating to concrete buildings, viz: That "the Portland cement shall be of the very best quality, ground extremely fine, and weighing not less than 112 lbs. to the striked bushel, and capable of maintaining a breaking weight of 350 lbs. per square inch, after being made in a mould and immersed in water during the interval of seven days." It must be admitted that, taken as a specification for cement, this regulation is rather vague, and as in all matters appertaining to the testing of cement great ex-

actness is required, and that a uniform and standard apparatus should if possible be adopted, I think that the Metropolitan Board of Works have it in their power, by somewhat enlarging on this regulation, to lead to the abolition of many abuses, and thus tend to the elucidation of many seeming contradictory results.

As the weight per striked bushel of a cement must evidently vary according to the means employed to fill the measure, it is essential that it should always be filled in the same manner. The apparatus which I use, and which I think meets all requirements, consists of a circular iron hopper or funnel perfectly smooth on the inside, into which the cement to be weighed is placed; at the small end it has a canvas stocking, which leads the cement into the zinc shoot, placed at an angle of 55°, the lower end of the shoot being five inches above the top of the measure. The measure, placed on a perfectly firm floor, on which there is no vibration, is never in any way touched during the process of filling, nor until after it has been carefully struck with a straight edge. When filling the measure the stocking may be held in the hand so as to regulate the run of the cement from the funnel. In a paper I read before the Institution of Mechanical Engineers, in Jan. 1875, when referring to the weight of cement, I said: A light cement is generally a weak one, though it may be of the requisite fineness; at the same time, a heavy cement if coarsely ground is also weak, and will have no carrying capacity for sand. As the more the clinker is burned the harder and heavier it becomes, and therefore more difficult to grind in the millstones, the heavy cements to be met with are almost invariably coarse ones; and as an underburned cement, from its softness, will be ground fine enough, but will be found deficient in weight, so it will be seen that the weight, unless taken in conjunction with the fineness, is no test as to the quality of the cement." This opinion I have found confirmed by subsequent experiments, the results of some of which are given in Table No. I. In each case the cement was weighed, tested as delivered, and also when ground; so that all would pass through a No. 50 sieve. The tensile strengths given being in each case an average of ten briquettes.

TABLE I.

	Residue per cent. after sifting through sieve having 2,500 meshes per square inch.	Weight per striked bushel.	Tensile strength on section 1 inch square.	
			7 days.	28 days.
			lb.	lb.
No. 1—				
Cement as delivered from manufactory	25	114	535	661
Cement ground to all pass sieve 2,500 meshes ..	Nil	104	572	not taken
No. 2—				
Cement as delivered	16	116	509	650
" ground..	Nil	109	542	675
No. 3.				
Cement as delivered	14	116¼	476	662
" ground..	Nil	112	505	710
No. 4—				
Cement as delivered	33	118½	693	728
" ground..	Nil	105	666	810

By examining these results, we find, firstly, that by fine grinding the weight per striked bushel is reduced, and secondly, that the tensile strength is increased, both at the expiration of seven and twenty-eight days from the time of gauging. That the weight per bushel should be less, is what would naturally be expected, as it is evident that the finer particles are less dense than the coarse, and also that they fall lighter into the measure. That the fineness to which a cement is ground should affect the tensile strength in so marked a degree, may be accounted for by the fact that the coarse particles in a cement have practically no cementitious property, being little better than so much sand. To prove this the following experiments were made with the core or coarse particles in a cement:—1. The residue that would not pass through a 625 mesh sieve was gauged with water, and, at the expiration of seven days, was found to be merely held together in a mass similar to so much sand, having a slight admixture of loam. 2. That which passed through the 625 mesh sieve, but would not pass through

the 2,500 mesh sieve, was gauged in a similar manner, and at the expiration of the same time was found to be in a similar condition. 3. That which passed through the 2,500 mesh sieve, but would not pass through a 4,900 mesh sieve, being gauged in the same manner, was at the expiration of the same time found to be in a similar condition. These experiments were made with a cement that was perfectly set in thirty minutes after gauging. In each of these cases the pats could be crumbled to pieces between the finger and thumb, and the granulations were the same in size and shape as before the water was put to them, thereby proving that the granulations themselves had no power of setting, but were simply held together by the infinitesimal particles of finely-ground cement, from which it was impossible to separate them. It, therefore, seems that the granular portion, or the core of a cement, has really a deleterious effect on its strength, and for all practical purposes may be considered only as so much sand.

TABLE II.

	Sample No. 1.		Sample No. 2.		Sample No. 3.	
	7 Days.	28 Days.	7 Days.	28 Days.	7 Days.	28 Days.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Cement as delivered from Works.. ..	535	661	509	650	481	650
Ditto all ground to pass No. 50 Sieve ..	572	—	542	675	505	710
Siftings only passed through No. 50 Sieve.	547	697	573	668	452	629

Table No. II. gives the results of further experiments made with the same object. It will be seen that in samples Nos. 1 and 2 the cement was actually improved by extracting the core that would not pass the No. 50 sieve; but sample No. 3, which was a very finely-ground cement, slightly deteriorated; and it will be further noticed that all three samples were improved by fine grinding. Though in this paper I am not going into the strength of mortars, it would be well to say that the fine grinding would give a more decided advantage in the case of mortars than in neat cement. Many people, even some manufacturers, consider the core to be the backbone of the cement, and to a certain extent they are in the right, but the result of these experiments proves that to be of value it must be ground. It is naturally the hardest burned particles which form the core, those which the mill stones have been unable to grind through their being of a harder nature than the rest of clinker. The core—therefore, as core, is really only so much sand in the cement—when ground acts in most instances beneficially and improves the quality of the cement.

TABLE III.

No.	Specific Gravity.	Weight per striked Bushel.	Residue per cent.		Tensile Strength per square inch.		Increase per cent
			No. 25 Sieve.	No. 50 Sieve.	7 Days.	28 Days.	
1	3.09	116	2	16	509	650	27.7
2	3.00	116½	¼	13	400	550	37.5
3	3.00	116½	0	14	471	594	26.1
4	2.99	118	4	28	605	772	27.6
5	2.96	116	4	26	586	767	30.9
6	2.95	113½	3	33	473	558	17.9
7	2.90	111	7	30	701	718	2.4
8	2.90	118½	8	33	693	728	5.0

Table III. gives the results of experiments made with eight samples of cement, showing the specific gravity, weight per bushel, fineness, tensile strength at seven and twenty-eight days, and the increase per cent. between those dates. If we examine the specific gravity and weight per bushel in conjunction with the fineness to which the cement is ground, it will be seen that a heavy weight per bushel and a heavy specific gravity denote a well-ground cement—while a heavy weight per bushel and a light specific gravity denote a badly-ground cement. It has been proposed to substitute the specific gravity for the weight per bushel when testing cement; but it must be remembered that the object of testing cement is not only to determine the actual strength of

the cement at a given date, but to be able to form a fairly-accurate opinion as to its probable behavior in practice. I therefore think that to do away with the weight-per-bushel test, would be, to say the least, undesirable, as when taken in conjunction with the fineness, a very fair opinion can be formed of the value of a cement—an opinion which can be confirmed by afterwards taking the specific gravity; in fact the specific gravity, weight per bushel, and fineness, bear a certain relative proportion to each other, indicating either a light or heavily-burned cement. By again referring to Table III we find that the cements having a light specific gravity are quick-setting cements, which in seven days have already attained great strength, but which show but little improvement afterward, while those having a heavy specific gravity are slower in setting, and at seven days do not show such good results but continue to improve for a longer period. It is unfortunately impossible to lay down an absolute rule by which to determine the value of a cement, as almost every property, whether to its advantage or disadvantage, which it possesses, may be traced to more than one cause, and therefore might lead to opposite results in practice; and when it is remembered that an opinion, to be of any practical utility, must be given in a few days, and before the cement is required for use, it becomes entirely a matter of experience and thorough knowledge of the process of manufacture, to be able to give a reliable opinion as to the suitability of a cement to the work for which it is intended, by reference only to the problematical tests. Having considered what I have called the problematical tests of cement, viz., its weight, fineness, and specific gravity, and shown the results which may be expected by this preliminary examination, there remain to consider the absolute test of tensile strength, and the manner in which it is carried out. The object of the test for tensile strength is to obtain the best possible results under certain conditions. The conditions are generally those already given in the extract from the regulations of the Metropolitan Board of Works. It is evident that to obtain the best results much must depend on the manipulation of the cement, the manner in which it is gauged, the amount of water which is used for the purpose, the care with which it is placed into and removed from the moulds, the length of time which is allowed to elapse after gauging before it is placed in the water, the form of the mould used, and many other minutiæ of manipulation which can only be acquired by actual experience and practice. The amount of water which is required to reduce a cement to a proper consistency, or technically to properly gauge it, varies from 16 per cent. to 20 per cent. A quick-setting cement generally requires a larger per-centage of water than a slow-setting one, but the exact amount required can only be determined by actual experiments with the sample under examination. The amount of water required also depends upon the skill of the manipulator, as an experienced gauger will bring the mass to a proper consistency with less water than another of less experience or skill, and as the amount of water used materially affects the result obtained, the importance of using a minimum cannot be overestimated. Many of the discrepancies which arise when testing cement are undoubtedly due to this cause. With the object of over-coming this difficulty I have devised a small machine for gauging cement, and I find that by its use less water is required, and that the operation of gauging is done much quicker, both points which materially affect to its advantage the result obtained. The custom seems to have become general that the briquettes should be placed in water twenty-four hours after gauging; this time, though it is perhaps convenient to gauge up on one day and place the briquette in water on the next, gives a slow-setting cement every chance, still it certainly does not act beneficially on a fairly quick-setting cement, and it is generally advisable to place the briquette in water as soon as it is possible to remove it from the mould without fear of damage; the twenty-four hours may be taken as the limit of time, as, though a cement which has not by then set sufficiently to bear removal from the moulds may be a fairly good cement, it is too slow in setting to be of much practical value.

Again, with regard to the area of

breaking section of the briquette, it is usual to specify that the cement shall carry so much on the square inch, and yet the briquette generally in use has a breaking section of 1.5 in. square, giving an area of 2.25 in. How this custom has arisen I am unable to say, but it would undoubtedly greatly assist in clearing up many of the discrepancies now to be met with if one uniform section and form of briquette were adopted; and inasmuch as the strength on the square inch is specified, it would seem natural that the briquettes should have that area of breaking section. It will be readily understood that the form of the briquette has much to do with the result obtained, and it is essential that the strain put on the briquette should be tensile only, all crushing forces being detrimental and often resulting in the fracture occurring elsewhere than at the smallest part, and hence giving a false result. Also, that the briquette should be capable of easy removal from the moulds in which it is gauged—avoiding all necessity of knocking the mould in order to remove it—as such is liable to injure the set of the cement.

There is another matter which seems to be overlooked, or at all events not estimated at its full value, by experimenters with cement, viz., the increase in strength between a briquette broken at the expiration of seven days, and at the expiration of twenty-eight days. Many cements will stand the ordinary test at seven days, and yet be utterly worthless at twenty-eight days; others will give a good result at seven days and improve but little afterwards, while a cement that gives a comparatively low result at the expiration of several days may, at the expiration of twenty-eight, have considerably increased in value. The result of the subjoined experiments shows that this is a most important matter in estimating the ultimate strength of a cement.

By an examination of Table IV it will be seen that No. 1 was a cement that actually satisfied all requirements at the expiration of seven days, and yet at twenty-eight days was actually worthless, being much blown, and consequently having no strength whatever; and it would undoubtedly have pulled to pieces any work in which it was used. Nos. 2 and 6 were both strong quick-setting cements, and showed good results at the expiration of seven days, in fact they seem in that short time to have attained almost their ultimate strength, as their increase during the next three weeks was but 2 and 5 per cent. The other samples show results varying from 20 to 40 per cent. increase in tensile strength between the seven and twenty-eight days, and it will be seen that at longer dates the quick-setting cements are by no means the strongest. The importance of fine grinding is again exemplified by examples Nos. 6 and 8. No. 6 is the cement as received from the works—33 per cent. of it would not pass through the No. 50 sieve. No. 8 is the same cement, but ground so fine that it would all pass the same mesh sieve—while in the cement as delivered, the increase in strength between the seven and twenty-eight days was but 5 per cent., though when ground it amounted to 21 per cent. In this paper I have treated solely of what may be considered good cements, and have given the result of the tests made with them under different conditions. The failure of a cement by expansion or contraction during the process of setting has not been brought under consideration, but it is needless to say that a cement which does either would be a dangerous cement to use, the only exception being that a good cement will sometimes blow if used too soon after it has left the mill and before it has had time to cool; such a cement

TABLE IV.

No.	Tensile Strength Section 1 in. Square.			Increase or Decrease per cent. at 28 Days.	Increase or Decrease per cent. at 3 Months.
	7 Days.	28 Days.	3 Months.		
	lbs.	lbs.	lbs.		
1	380	210	..	−44.73	
2	701	718	728	+ 2.42	+ 3.85
3	510	647	716	+26.86	+40.39
4	6 5	772	826	+27.60	+36.52
5	476	662	..	+39.07	
6	693	728	..	+ 5.05	
7	589	764	901	+29.88	+52.97
8	666	810	..	+21.62	

would, after being properly warehoused, be perfectly reliable. The deductions which I draw, and which I have endeavored to prove from the experiments, are:—1. That the weight per striked bushel, unless taken in conjunction with the fineness to which the cement is ground, is absolutely valueless as a guide to the quality of a cement, and that therefore the two should always be taken in combination, and that it is also advisable when possible to take the specific gravity. 2. That the finer a cement is ground the less it will weigh per striked bushel, but that it will at the same time be stronger. 3. That the core or coarse particles in a cement act deleteriously, and can be compared only to so much sand. 4. That to be able to form a true opinion of the value of cement, briquettes should, when practicable, be tested at twenty eight days as well as at seven, and that the greater the increase per cent. is between those dates the stronger and harder is the cement likely to become. The details of the weight and fineness, and other matters deduced from the foregoing tests, I have embodied somewhat in the form of a Specification, which I think meets most requirements, but the purposes for which a cement is to be used must of necessity govern many clauses. Thus:

SPECIFICATION.

Sample.—From each delivery of cement on to the works a sample of about one bushel will be taken indiscriminately from at least twelve sacks or casks, as the case may be, and will be subjected to the following tests, with the whole of which it will have to comply. The sample thus taken will be considered to indicate the quality of the entire delivery.

Fineness.—The cement to be so finely ground that it will all pass without leaving any residue when sifted through a copper wire sieve having 625 holes to the square inch, and when sifted through a similar sieve having 2,500 holes to the square inch, the residue, or that which is unable to pass through, shall not be more than 15 per cent. of the bulk before sifting.

Weight.—The weight per striked bushel to be not more that 116 pounds nor less than 108 pounds, but the weight must in all cases depend upon the fineness; thus, according to requirements, a cement which, when sifted through a sieve, having 2,500 holes to the square inch leaves a residue of from 12 to 15 per cent., must weigh not less than 112 pounds per striked bushel; should the residue be from 8 to 12 per cent. the minimum weight to be 110 pounds, and should there be less than 8 per cent. residue, the minimum weight to be 108 pounds per striked bushel. The bushel measure to be placed on a level floor where there is no vibration, and in every case filled from a zinc or other smooth-surfaced shoot, placed at an angle of 55 degrees, the lower end of the shoot to be 5 inches above the top edge of the measure. The cement to be allowed to run continuously along the shoot until the cement in the measure is well piled up, when it is to be struck level with a straight edge. In no case is the measure to be in any way touched or shaken, until it has been struck.

Specific Gravity.—The specific gravity to be not less than 2.95 nor more than 3.1.

Tensile Strength.—Twenty briquettes to be gauged from each sample, ten to be broken at the expiration of seven days from the date of gauging, and ten at the expiration of twenty-eight days from the date of gauging. Those broken at seven days to carry an average weight of 400 pounds per square inch of section without fracture, and those broken at twenty-eight days to show an increase in strength of 25 per cent. over those broken at seven days.

The following particulars are to be observed in gauging the cement to form the briquettes: The contractor to use any form or section of mould he chooses in which to make the briquettes, provided always that the breaking sectional area of the briquettes be not less than one square inch. The moulds in which the briquettes are made to be placed on glass or other non-porous beds. The amount of water used for gauging the cement not to be more than 19 per cent. of the whole. The briquettes to be removed from the moulds and placed in water within twelve hours from the time of gauging and allowed to remain therein until they are due for breaking (which will in every case be reckoned from the time of

gauging and not of placing in water), and to be broken immediately on being taken out of the water.

Expansion or Contraction. — Pats about 3 or 4 inches square and about $\frac{3}{4}$ inch in thickness (gauged with the same per centage of water as is used in forming the briquettes), placed on pieces of glass, to be immersed in water within four hours after gauging, and to show neither cracks on the edges nor on the surface, nor deviation in form when examined at the expiration of seven days.

THE SLIPPING OF LOCOMOTIVES.

From "Engineering."

Some two years or so ago prominent attention was directed to this matter by M. Rabeuf, who carried out on the Northern Railway of France some experiments which certainly yielded startling results. These experiments were made with a four-coupled engine having coupled wheels 7 ft. in diameter, and carrying a total load of 27 tons. In fine weather M. Rabeuf found that this engine, when running light at the high speed of 74½ miles per hour down a gradient of 1 in 200, apparently slipped continuously to the extent of 19 per cent., while other engines also gave results of a very similar kind, the slipping at maximum speeds apparently varying from 13 to as much as 25 per cent. According to M. Rabeuf's observations, the percentage of slipping increased with the speed, and was greater on descending than ascending gradients.

These results obtained by M. Rabeuf naturally received considerable attention, and they have been analyzed in France by MM. Desmousseaux de Givre and J. Morandière, and in Italy by Signor Oppizzi. We have not space here to enter into the details of the investigations made by these engineers, but we may say that the general explanation arrived at is to the effect that at very high speeds not only is the coefficient of adhesion modified, but during certain portions of the revolution of the driving-wheels the pressure of the wheels on the rails is materially affected by the action of the unbalanced rotating parts, &c. When working at a high grade of expansion, as would probably be the case with a light engine descending an incline, the effective moment of rotation due to the action of the steam in the cylinders, of course, varies considerably at different parts of a revolution, and the coincidence of a maximum moment of rotation with the diminution of adhesion pressure above referred to, might, of course, result in slipping for a certain portion of each revolution of the driving-wheels. Signor Oppizzi, however, came to the conclusion that this action is not likely to occur at the ordinary speed at which trains are worked, and that M. Rabeuf's results were thus of an exceptional character.

While, however, M. Rabeuf's experiments have been thus discussed, there seems to have been no effort to check the accuracy of his deductions until the matter was again taken up on the Northern Railway of France last year by M. J. de Laboriette, who has lately contributed to the *Revue Générale des Chemins de Fer* a very interesting memoir on the subject, describing his mode of experimenting and the results which he has obtained. The apparatus employed by M. J. de Laboriette in his researches was arranged to obtain electrically, by the use of a Morse printer, a record of every revolution made by the driving-wheels. According to the arrangement first employed, one pole of a battery was placed in communication with the driving-axle of the engine on which the experiments were being made, while the other pole was connected to a long metallic brush, insulated and mounted on the driving horn-plate of the outside frame of the engine, so that at each revolution the brush came into contact with the outside crank on the driving-axle. The circuit was thus completed once during each revolution, and a Morse printer being placed in the circuit a mark was made on a traveling band of paper for every revolution made by the

driving-axle. It was found, however, on trial that this arrangement was not entirely satisfactory, the contact between the metallic brush and the crank arm being very brief, and not always sufficiently perfect to secure the completion of the circuit, and there was, therefore, substituted for the brush arrangement an "interrupter" worked from a reciprocating part of the engine, and arranged so as to complete the circuit once during every revolution. This "interrupter" consisted simply of a vibrating lever connected to one pole of the battery, and carrying a spring which during a portion of the oscillation of the arm rested upon an insulated surface, and during the remainder of the oscillation completed the circuit by bearing upon a metallic arc in electric communication with the other pole of the battery. The revolutions of the driving wheels being recorded in the manner just described, there remained to be recorded the distance run by the engine, and this was done by an observer, who marked on the traveling band of paper the passage of the engine past each kilometer post, the instant of passing being announced by a second observer striking a bell. Slight errors, due to the observers, or to the want of absolute accuracy in the spacing of the kilometer posts, were eliminated, by making each experiment continuous over a number of kilometers, while the apparatus was fitted to a dynamometer van, so that observations of the tractive force exerted by the engine could be simultaneously made.

The experiments carried out by M. J. de Laboriette were carried out on six locomotives of three different types, five of the engines having each four coupled wheels, while the sixth was a Crampton engine with a single pair of driving wheels. In each case the circumference of the wheels was obtained with great care, not by measuring the diameter, but by moving the engines slowly on the rails and measuring the distance traversed for a complete revolution. The trains hauled during the experiment varied in length from 12 to 22 carriages, and the speeds from 70 to 90 kilometers (43½ to 56 mlles) per hour, while the results show that under the conditions existing on these trials no slipping whatever occurred. In fact, the agreement between the actual distances run and the distances as measured by the revolutions of the driving wheels, as recorded by the tables in the manner above referred to, is extraordinarily close, and speaks most highly for the accuracy with which the measurements were made, the difference never exceeding a small fraction of a revolution per kilometer.

M. J. de Laboriette's experiments may be considered to entirely set at rest any doubt which may have arisen as to the partial slipping of driving wheels under the ordinary conditions of locomotive working, proving as they do that no such continuous slipping exists, and that hence this supposed action has not to be taken into consideration as a cause of wear and tear. We trust that on some future occasion M. J. de Laboriette may be able to extend his researches (if he has not already done so) to the investigation of the action which takes place at the exceptionally high speeds attained by M. Rabeuf in his experiments, so that the results obtained during these trials may be checked by independent observations. Speeds of over 60 miles per hour are now common with many of the express trains in this country, and it is daily becoming of more importance that the working of locomotives and the resistances of trains at these high speeds should be thoroughly investigated. Theory has shown that at exceptionally high speeds partial slipping may be produced from the causes to which we have already alluded, and it appears to us well worth while to check the deductions of theory by experiment, and to ascertain whether with locomotives, as now proportioned, there exists an obstacle to the attainment of very high speeds which has hitherto not been generally appreciated. So far the investigation of this matter has been left to Continental engineers, but there is every reason why, with the fast traffic to be dealt with here, it should be made the subject of careful experiment in this country, and we hope, therefore, to hear of its being taken up thoroughly by some of our locomotive superintendents.

GASES, LIQUIDS, AND SOLIDS.

From the "English Mechanic and World of Science."

THE series of experiments recently made by Mr. J. B. Hannay and Mr. J. Hogarth, the most remarkable outcome of which is the production of crystallized carbon, carry the work of Pictet and Cailletet another step forwards in a slightly different direction. Those able investigators demonstrated that gases could be converted into solids, and Messrs. Hannay & Hogarth have now shown that there is a perfect continuity between the gaseous and the liquid states, and have supplemented the labors of Dr. Andrews by some elaborate and valuable researches which have been so far rewarded by the crowning discovery of artificial diamonds. The experiments were primarily commenced with the view of throwing further light on what Dr. Andrews called the "critical state" of matter. Carbonic acid at 35.5° C., and under a pressure of 108 atmospheres is, according to Dr. Andrews, midway between a gas and a liquid, and the chemist would be puzzled to assign reasons for classing it under one head in preference to another. If the property of dissolving solids is peculiar to liquids, there would necessarily be some deposit of solid from a solution when the latter was passing the critical point, but if not the fact would be a further proof of the continuity of the liquid and gaseous states. At first Messrs. Hannay & Hogarth adopted a modification of Dr. Andrews' apparatus, and as this will have an interest for many of our readers we briefly describe it. Wrought iron hydraulic tubing about ½ inch internal and 1 inch external diameter was used as the earliest pressure appliance. The length was 9 inches, and a side tube for the insertion of the manometer was welded on. The ends were closed by strong screw-caps, through one of which the experimental tubes were passed, while the other was used as a kind of gland, through which the pressure-screw (¼ inch diameter, 30 threads to the inch) was admitted to the tube. The packing consisted of a solid plug of rubber, about ½ inch thick, placed in the caps; in the case of the screw, the hole through the rubber was lined with thin leather, well soaked in lard, while, to prevent the experimental tubes being forced out through the hole in the cap, a spreading of the gas was produced, which bore against a strong leather washer. In cases where very high pressures were required, the tubes were cemented in with oxychloride of zinc. This method of packing will be a hint of some use to experimentalists, for although pressures up to 880 atmospheres were sometimes reached, the apparatus was free from leakage, and was as tight with mercury as with water. When high temperatures were also required, the experimental tube, after leaving the pressure-cylinder was bent down and up and passed into an air-bath of two concentric iron cylinders, with mica windows for observing the effects. The method of carrying out the experiments was much in the following way: A glass tube was fixed in the apparatus previously filled with mercury, and a small quantity of alcohol was drawn in by reducing the pressure. A fragment of fused potassic iodide was then dropped in and heat was applied to boil the alcohol and expel the air, when the tube was sealed by the blowpipe. Precautions were taken to prevent the liquid alcohol from touching the potassic iodide while the tube and its contents were raised to a temperature of 300° C. Pressure was then increased until the alcohol was reduced to about the volume occupied in its fluid state, when the fragment of potassic iodide was seen to dissolve gradually and completely, although the alcohol was in the condition of a gas, using that term in Dr. Andrews' sense of a fluid at any temperature above its critical point, which, in the case of alcohol, according to Messrs. Hannay & Hogarth, is 234.4° C. On slowly withdrawing the screw no deposit occurred, but when the screw was turned out rapidly a crystalline film appeared on the glass, and in some cases a cloud of fine crystals in the menstruum, both of which could be easily redissolved by

increasing the pressure. The existence of the solvent power above the critical point being thus established, experiments were made with other solvents and solids. Some interesting information was gained by these investigations, and some more or less valuable discoveries may be expected to spring from them. A solution of sulphur in bisulphide of carbon, for instance, showed no sign of separation when raised 50 centigrade degrees above the critical point. Selenium also remained in solution in the same menstruum when heated above the critical point, but a chemical action took place, sulphide of selenium being probably formed. The apparent solubility of arsenic was also probably due to the formation of a sulphide. With many other substances, chemical changes appeared to occur without signs of solution. An interesting experiment to determine whether the absorption spectrum of a substance dissolved in a fluid above the critical point would be the same as in liquid solution, or when acted upon in the solid state, was answered in the affirmative, for a solution of anhydrous cobaltous chloride sealed in a tube, and heated beyond the critical point showed no difference beyond a fainter and more nebulous character of the bands, caused by expansion: their position was not changed. At the suggestion of Prof. Stokes, a similar experiment was tried with chlorophyll, with a similar result. Many other experiments were made, but we must refer those interested to the full description which will be issued in the *Proceedings* of the Royal Society. The investigations, so far as they have gone, are but the starting-point for others, and we may fairly expect a great development of this branch of research within the present year. The most interesting outcome of the present experiments is the discovery of the artificial production of the diamond, a supplementary paper on which, by Mr. Hannay, was read at a recent meeting of the society. While pursuing the investigation we have referred to briefly above, Mr. Hannay noticed that many bodies, such as silica, alumina, and oxide of zinc, insoluble in water at ordinary temperatures, dissolve to a large extent when treated with water-gas at high pressures. It occurred to him that a solvent might possibly be found for carbon, and as the gaseous solutions nearly always yielded crystalline solids on withdrawing the solvent or lowering its solvent power, it did not seem improbable that carbon might be obtained in the crystalline or diamond state. A number of experiments were accordingly made with charcoal, lampblack, graphite, but instead of solution, only a chemical action was induced. A curious reaction was, however, noticed, which seemed likely to tend to further discovery by furnishing carbon in the nascent state, and consequently easily soluble. When a gas containing hydrogen and carbon is heated under pressure in presence of certain metals, its hydrogen is attracted by the metal, and its carbon left free. That discovery, which is a very important one, is probably explained, as suggested by Prof. Stokes, by the discovery of Profs. Liveing and Dewar, that at high temperatures hydrogen has a strong affinity for certain metals, notably magnesium, with which it forms remarkably stable compounds. Now Mr. Hannay found that when the carbon is set free by this action of the hydrogen in the presence of a stable compound containing nitrogen, the whole being nearly at red heat and under enormous pressure, the carbon is so acted upon that it can be obtained in the clear transparent form of the diamond. The "stable compound containing nitrogen" is, however, for the present his secret. The greatest difficulty he has found is the construction of an apparatus strong enough to resist the enormous pressure, combined with a high temperature, for while the 1 inch hydraulic tubing sufficed for the earlier experiments, and withstood pressure ranging up to 880 atmospheres, tubes constructed on the gun-barrel principle, having a bore of half an inch, and an external diameter of four inches, were torn open in nine cases out of ten by the pressure found necessary to crystallize carbon. Mr. Hannay, we understand is in treaty with the makers of steel tubes for some specially strong specimens, and it is evident that we have not heard the last of his experiments, though the cost of the diamonds he has at present produced is necessarily far higher than the prices asked for similar crystals of nature's production. According to Mr.

Hannay, the carbon he obtained is as hard as natural diamond, a statement corroborated by the evidence of Mr. Maskelyne, and is also in crystals with curved faces belonging to the octahedral form. These burn readily on thin platinum foil over a blowpipe, and when ignited by an electric current in oxygen show a composition of 97.85 per cent. of carbon. Immersed in hydrofluoric acid for two days, no sign of solution is exhibited even when boiled. The crystals answer other tests, but as yet no perfect crystals have been submitted to experts, only crystalline fragments; and as the position of science is ever one of scepticism until the truth is demonstrated, the authoritative acknowledgment of Mr. Hannay's discovery will not be made until further experiments have enabled him to prove transmutation of carbon beyond the shadow of a doubt. The apparatus and all analyses are to be fully described in a paper to the Royal Society, but there is little question that Mr. Hannay is the first to show specimens of crystallized carbon produced in the laboratory of the chemist. We incline to the opinion, however, that his researches into the solubility of solids in gases will ultimately be found of more scientific value than his discovery of artificial diamonds.

EUPHRATES VALLEY ROUTE TO INDIA.

By W. P. ANDREW.

From "Journal of the Society of Arts."

SELDOM has the public mind—I may say that of Europe—been so completely engrossed as at this moment by the Central Asian question, owing rather to the magnitude and uncertainty of events, to which it may at a future time give rise, than to its more immediate and palpable consequences.

Here, in England, it is not surprising that the recent movements of Russia—taken in conjunction with the position in Afghanistan of our heroic countrymen and their gallant brothers in arms, whether Mohammedan or Hindoo—should excite men's minds, and should make us more determined than ever for the maintenance of our *prestige* in Europe and the safety of our Empire in the East. But while, in our desire to avoid political complications, we have devoted ourselves, with much assiduity, to the discussion of minor geographical questions, we have overlooked the simplest and most obvious means of checkmating the possible designs of Russia, by closing the gates of India, the Bolan and the Khyber, and by a parallel movement along the Valley of the Euphrates. It is right, therefore, at the present juncture, once more to invite attention to the proposed establishment of a direct and rapid route to our Eastern possessions, by the ancient highway of the Euphrates.

In the proposal to restore this ancient route—once the highway of the world's commerce, and the track of the heroes of early history—by the construction of a railway to connect the Mediterranean and the Persian Gulf, we have at hand an invaluable and perfectly efficient means at once of thwarting the designs of Russia, if they should assume a hostile character; of marching hand-in-hand with her, if her mission be to carry civilization to distant lands; and of competing with her in the peaceful rivalry of commerce.

Of all the lessons which recent wars have taught us, none is more emphatic than this, that henceforth the power of nations must be upheld by the knowledge and use of mechanical appliances. Among the most important of these are railways, as we saw in the Franco German war. A vague presentiment of this marvelous revolution had long existed, but it had to struggle against apathy and deep-seated prejudice. The true secret of national supremacy has, however, now been brought home with irresistible force to the most reluctant mind; and it behooves us to brace ourselves anew for a more determined progress, if we would retain the prestige and influence we have hitherto enjoyed as a great nation.

In the Crimean war we saw, with certainty, where the power of the Czar first

gave way. The telegraph and rail were the missing links in his armor. He had built fortresses of colossal magnitude, collected resources astonishing from their variety and abundance; his generals were selected with consummate skill, while over the persons and property of his subjects he exercised unlimited control. But, had the Czar been able to whisper his commands with lightning speed, and been obeyed with promptitude, how different might have been the result! The giant aggressor was, by a handful of invaders, with telegraph and steam in connection with the bases of their operations, defeated and humiliated on the soil of holy Russia herself.

We all now know how alive Russia has now become to the necessity of following up her advances by improved means of communication. It is inconceivable that any power but England, having either means or credit at command, would hesitate how to act under such circumstances as those in which we are placed. To us it has been a continual reproach that we are never ready for the emergencies which we might readily have foreseen. Let us not refuse, therefore, to learn wisdom by the experience of the past, or some day we shall assuredly be called on to spend untold treasure to retrieve disasters which a little timely forethought would have enabled us to avert.

Few facts bear more conclusive testimony to the sagacity of the ancients, when the limited amount of their geographical knowledge is remembered, than the tenacity with which commerce adhered to the direction given to it by them, and the readiness with which it returns to any of those channels when temporarily diverted by political events, or geographical discoveries. The overland route from Europe to India, by the Isthmus of Suez and the Red Sea, is certainly as old as the days of the early Phœnician navigators. The navigability of the Euphrates was tested long before Trajan ever sailed on its waters, and was re-visited by the Italians in the eleventh century, and our own merchants in the days of Elizabeth, as the best way to the East; whilst the value of the Indus, as the shortest and easiest route for the commerce of India, not only with Central Asia and the North of Europe, but with the whole of the West, was fully recognized by the later Romans in the seventh century. When the rapid progress of the Mohammedan arms had wrested Egypt from the Byzantine power, and thus closed the overland route of Suez to the Greek merchants, they forthwith turned to other means, and sought out a new channel by which the productions of the East might be transmitted to the great Emporium of the West. The route thus discovered was that by the Indus. The rich and easily stowed products of India were carried up by this great river as far as it was navigable, thence transported to the Oxus, down whose stream they proceeded as far as the Caspian Sea. There they entered the Volga, and sailing up it, were carried by land to the Tanais (the Don), which conducted them into the Euxine Sea, where ships from Constantinople waited their arrival.

Various causes concurred in restoring liberty and independence to the cities of Italy. The acquisition of these roused industry, and gave motion and vigor to all the active powers of the human mind. Foreign commerce revived, navigation was attended to and improved. Constantinople became the chief mart to which the Italians resorted. There they not only met with favorable reception, but obtained such mercantile privileges as enabled them to carry on trade with great advantages. They were supplied both with the precious commodities of the East, and with many curious manufactures, the product of ancient arts and ingenuity still subsisting among the Greeks. As the labor and expense of conveying the productions of India to Constantinople, by that long and indirect course which I have described (the route by the Indus, the Oxus, the Caspian, and the Volga), rendered them extremely rare, and of an exorbitant price, the industry of the Italians discovered other methods of procuring them in greater abundance, and at an easier rate. They sometimes purchased them at Aleppo, Tripoli, and other ports on the coast of Syria, to which they were brought by a route not unknown to the ancients. They were conveyed from India by sea, up the Persian Gulf, and, ascending the Euphrates and Tigris, as far as Bagdad, were carried by land across the desert of Palmyra, and from

thence to the towns on the Mediterranean.

The discovery of the long but easy route by the Cape of Good Hope, combined with the deadly feuds between the Christians of the West and the Mohammedan nations that held the countries of the Nile and the Euphrates, for a time diverted the stream of commerce from those routes. It has not been so, however, with the Indus to the same extent. If the revival of the Overland Route, and the impending re-opening of the Euphrates as the highway to the East, are evidences of a return to old paths, the continuance of a commerce with Central Asia and Northern Europe by way of the Indus, and the two great gates of India, the Khyber and Bolan Passes, is a pregnant proof of the tenacity with which trade adheres to its old channels, and of the sagacity which originally selected that direction for the produce of the East. However great may have been the changes of masters and manners in the territories between the Indus and the Bosphorus, a portion of the tide of commerce has flowed, and does still flow, as it did in the seventh century.

When the late Sir Alexander Burnes was in Lahore, in 1831, he found English broadcloth sold in the bazaar that had been brought, not from Calcutta, but from Russia; and, when he penetrated further into Central Asia, met, at Bokhara, with a merchant "thinking of taking an investment of it to Loodhiana, in India, where he could afford to sell it cheaper than it was to be had there, notwithstanding the length of the journey."

The countries which our future highway to India will traverse have been, from remote antiquity, the most interesting in the world. On the once fertile plains, watered by the Euphrates and Tigris, the greatest and most glorious nations of antiquity arose, flourished, and were overthrown. The earliest home of the genius of civilization—the scene of great events in the early history of the world, now shrouded in the dust of ages, or dimly discerned through the long vista of many centuries—the land of the Assyrians, Babylonians, and Chaldeans; where the daughters of Zion sat and wept; where lay the track of Xenophon and his heroic 10,000 Greeks—the center of the conquests of the Macedonians; where once stood the proud capitals of the Sassanides and of the Caliphs, now deserted and tenantless—these regions must ever possess a fascination and interest for all mankind.

The first city of the new earth was built upon the banks of the "Great River." The tower of pride, erected by the post-diluvian population, cast a shadow over its waters. The Euphrates intersected Babylon, the "Golden City," the "Glory of Kingdoms," the great capital of the Chaldean Empire—now a desolation among the nations, her broad walls utterly broken, her high gates burnt with fire. With Babylon are associated the names of Nebuchadnezzar and Belshazzar, of Daniel and Darius, of Cyrus and Alexander. The grand prophet of the captivity, and the energetic apostle of the new era, had their dwelling within her walls. Ere even a brick was made upon the Nile, Nineveh and Babylon must have had thriving and busy populations.

Twice in the world's history mankind commenced the race of civilization on the Mesopotamian rivers. Twice the human family diverged from their banks to the east, the west, and the north. Arts and sciences made the first feeble steps of their infancy upon the shores of these rivers. Very early in history we know that Babylon was a great manufacturing city, famed for the costly fabrics of its looms. At a more recent date, the Chaldean kings made it a gorgeous metropolis; Alexander of Macedon made it the port of the Indian Ocean and the Persian Gulf, and he proposed to render it the central seat of his imperial power.

The countries through which the Euphrates flows were formerly the most productive in the world. Throughout these regions, the fruits of of temperate and tropical climes grew, in bygone days, in profusion. Luxury and abundance were universally diffused. The soil everywhere teemed with vegetation. Much of this has since passed away. Ages of despotism and misrule have rendered unavailing the bounty of nature. But the land is full of hidden riches. The natural elements of its ancient grandeur still exist in the inexhaustible fertility of the soil, and in the chivalrous character and bearing of many of the tribes; and the day cannot be far distant

when it is destined to resume its place amongst the fairest and most prosperous regions of the globe.

The wondrous fertility of Mesopotamia was, in early times, carried to its utmost limit by means of numerous irrigation canals, with which the country was everywhere intersected, and some of the largest of which were navigable. These excited the wonder and interest of Alexander the Great, who, after his return from the conquest of India, examined them personally, steering the boat with his own hand. He employed a great number of men to repair and cleanse these canals.

Herodotus, speaking of Babylonia, says:—

"Of all the countries I know, it is, without question, the best and the most fertile. It produces neither figs, nor vines, nor olives; but, in recompense, the earth is suitable for all sorts of grain, of which it yields always 200 per cent., and, in years of extraordinary fertility, as much as 300 per cent."

These regions need only again to be irrigated by the life-giving waters pouring down, ever cool and plentiful, from Arrarat—that great land-mark of primeval history, now the vast natural boundary-stone of the Russian, Turkish, and Persian empires—to yield once more in abundance almost every-thing that is necessary or agreeable to man. Many acres, now wasted, might be covered with cotton, tending to the employment of the millions of spindles of our land.

It is not too much to say that no existing or projected railroad can compare in point of interest and importance with that of the Euphrates Valley. It will bring two quarters of the globe into juxta-position, and three continents—Europe, Asia, and Australia—into closer relation. It will bind the vast population of Hindostan by an iron link with the people of Europe. It will inevitably entail the colonization and civilization of the great valleys of the Euphrates and Tigris, the resuscitation, in a modern shape, of Babylon and Nineveh, and the re awakening of Ctesiphon and Bagdad as of old.

It is by distance and difficulties of intercourse that the distinctions of creeds and races are chiefly upheld. Annihilate space, and the great barriers that separate people—the differences of manners and customs, of modes of thought and feeling, of doctrines and dogmas, of precepts and prejudices, that keep up these barriers—gradually disappear, as barbarism, superstition and ignorance give way to the superior and irresistible force of civilization, truth and enlightenment.

Although various routes have been suggested with the view of bringing Great Britain, by means of railway communication, into closer connection with India and her other dependencies in the East, and of securing, at the same time, the immense political and strategic desideratum of an alternative highway to our Eastern possessions, there is none which combines in itself so many advantages as the ancient route of the Euphrates—the route of the Emperors Trajan and Julian, in whose steps, in more recent times, the Great Napoleon intended to follow, when the Russian campaign turned his energies in another direction.

The special advantages which render this route superior to all others are briefly these:—It is the most direct route to India. It is the shortest and the cheapest, both for constructing and working a railway, so free from engineering difficulties, that it almost appears as though designed by the hand of Nature to be the highway of nations between the East and the West; the most easily defensible by England—both of its termini being on the open sea; and the most likely to prove remunerative.

Both from an engineering and a political point of view, the Euphrates route undoubtedly possesses great advantages over any of the others which have been proposed. All the routes which have been suggested from places on the Black Sea are open to the fatal objection that, while they would be of the greatest service to Russia, they would be altogether beyond the control of Great Britain, while the engineering difficulties with which they are surrounded are, of themselves, sufficient to exclude them from practical consideration.

This has been fully established by the evidence of the witnesses examined by the Select Committee of the House of Commons, which, in 1872, investigated the merits of the various proposals for connecting the Mediterranean and the Black Sea with the Persian Gulf.

In the course of the investigation by the Committee, it was conclusively demonstrated that the proposed Euphrates Valley Railway is an eminently feasible undertaking in an engineering sense; that the route of the Euphrates and the Persian Gulf is decidedly preferable, in respect of climate, to that of Egypt and the Red Sea; that, as regards the safety and facility of the navigation, the Persian Gulf also has by far the advantage; that the proposed undertaking would be of great commercial moment, and, if not immediately profitable, at all events, that it would be so at a date not far distant; and, finally, that it would be of the highest political and strategic importance to this country.

It is unnecessary to quote in detail from the evidence taken by the Committee, but, in order to show how authoritative were the conclusions in favor of the undertaking aimed at by the Committee, I may state that the engineering facilities which exist for the construction of a railway from the Mediterranean to the Persian Gulf were demonstrated by the evidence of the late General Chesney, the veteran explorer of the route; by Captain, now Admiral, Charlewood, of the Royal Navy, and Mr. W. F. Ainsworth, two of the officers attached to the Euphrates Expedition; by Sir John Macneill, Mr. Telford Macneill, Mr. W. J. Maxwell, Sir Henry Rawlinson, Captain R. F. Burton, and Captain Felix Jones. The advantages of the route, in respect of the climate and productiveness of the country to be traversed, were shown by the evidence of General Chesney, Mr. Eastwick, M. P., Captain Felix Jones, General Sir Henry Green, Colonel Malcolm Green, Mr. Consul Barker and others. Mr. Barker, who had resided twenty-six years as Vice-Consul and Acting Consul at Seleucia, Antioch, and Aleppo, and has, perhaps, as intimate an acquaintance with the country as any man living, stated in an official report, addressed by him to Lord Granville, that—

"A railway through Mesopotamia, as a route to India, would not, at first, be productive of much to a company from traffic, but in a few years—certainly before the railway could be finished—the cultivation of grain would increase a hundredfold, and would go on increasing a thousandfold, and would attain to a magnitude and extension quite impossible to calculate, because bad harvests are almost unknown in these parts, for there is always plenty of rain and a hot sun to ripen the corn. Populous villages would spring up all along the line, as there is abundance of sweet water everywhere. Cereals can be grown there so cheaply that no country the same distance from England—say, for instance, Russia—could compete with it at all. And, if Great Britain finds it necessary to rely more on the importation of foreign corn, where could a better field be found than the fertile plains of Mesopotamia, the cradle of mankind, which has all the advantages of climate, soil, sun and water in its favor."

The facility of the navigation of the Persian Gulf was testified to by Mr. William Parkes, Consulting Engineer to the Secretary of State for India for Kurrachee and Madras harbors, and also in a correspondence published by Captain A. D. Taylor, late of the Indian Navy. Mr. Edwyn Dawes gave some useful information of the great extension of commerce at all the ports of the Persian Gulf.

The advantages of the proposed undertaking from a military point of view were placed beyond question by the evidence of General Chesney, of Captain Tyler, R. E., and of those experienced soldiers, Sir Henry Green and Colonel Malcolm Green, and more especially by the weighty testimony of Field Marshal Lord Strathnairn; while its importance in a political sense was established by many witnesses, amongst whom I may instance Sir Bartle Frere, the late lamented Sir Donald McLeod, Mr. Palgrave, Colonel Herbert, her Majesty's Consul-General at Bagdad, Mr. Eldridge, Consul-General at Beyrout, and, pre-eminently, the "Great Elchi," the venerated Lord Stratford de Redcliffe.

Other nations, whose interests in the East are incomparatively less than ours, either on political or commercial grounds, have, in recent years, made great advances in extending their communications in an easterly direction.

The establishment of steam communication by the Messageries Maritimes on the Route of the Red Sea, to Calcutta and other Eastern ports, shows the im-

portance attached by the French to the extension of their commercial relations with the East. A Russian line of steamers has been established, to run between Odessa and Bombay by the route of the Suez Canal, and the Italians and Australians are actively competing for a share in the Eastern trade. Even those who see no danger in the policy of annexation pursued by Russia, will admit that the Russian roads and railways now being pushed towards Persia and Afghanistan, if designed with pacific intentions, prove, at all events, the anxiety of the Russian Government to compete with us for the trade of Central Asia, the Punjaub, and Northern India. But the carriages and trucks ostensibly designed for peaceful and commercial purposes are so constructed as to be equally available for the conveyance of troops with munitions of war.

It behooves us, therefore, to be careful that we do not stand still in the career of improvement, and be left behind in the race by other nations, however friendly. Political disturbance in Europe might at any moment deprive us of our communications with India *via* Egypt. The canal, glorious work as it is, might be suddenly rendered useless. So long as the Indian Empire subsists, the connection between India and this country must be kept up. If that connection were interrupted for many months, the integrity of our Eastern Empire might be seriously menaced. England maintains her position in India mainly by force of arms; and it is a principle, both of war and of common sense, to take the most efficient means at our command to keep open the lines of communication between the base and the field of operations. Hence the necessity of establishing an alternative route, even if it were not a better one. But that by the Euphrates, the most ancient of all, is at once the shortest, the easiest, and the safest, and it can never be superseded by any other offering superior advantages.

Apart from the general question of the advantage, on strategic grounds, of possessing an alternative and accelerated route to our Eastern dominions, it is a matter of the greatest importance that, in case of an emergency we should be able to send troops to India at any season of the year. Viewed in this light, the Euphrates route presents a striking contrast to that *via* Egypt, which, during a portion of the year, could not be used for the transport of troops without a serious sacrifice of life, in consequence of the excessive heat of the Red Sea. The Euphrates route, on the other hand, would be available for this purpose at all seasons.

The substitution of Kurrachee for Bombay as the European port of India would, even by the Red Sea route, give us an advantage of some 500 miles; but, if the Euphrates route were once established, the adoption of Kurrachee as the European port of India would necessarily follow, and India would thus be brought upwards of 1,000 miles nearer to us than at present; while, during the monsoon months, the gain would be still greater, as the route between the Persian Gulf and Kurrachee is not exposed to the severity of the monsoon, which, it is well known, renders a divergence of some 500 miles necessary during a portion of the year on the voyage from Bombay to Aden. Kurrachee is now in railway connection with Lahore and Calcutta, and, when the railway system of the Valley of the Indus is completed as far as the Bolan and Khyber Passes, and extended to Candahar, the safety of India would be insured.

May I be permitted to repeat the words which I ventured to urge upon Lord Palmerston upwards of twenty years ago, when I accompanied, in support of the Euphrates Valley Railway, one of the largest and most influential deputations that ever waited upon a minister:—

"The grand object desired is to connect England with the north-west frontier of India by steam transit through the Euphrates and Indus Valleys. The latter will render movable to either the Khyber or the Bolan, the two gates of India, the flower of the British Army cantoned in the Punjaub; and the Euphrates and Indus lines being connected by means of steamers, we should be enabled to threaten the flank and rear of any force advancing through Persia towards India. So that by this great scheme the invasion of India would be placed beyond even speculation, and it is evident that the great army of India of 300,000 men being thus united to the army of England, the

mutual support they would render each other would quadruple the power and ascendancy of this country, and promote powerfully the progress, the freedom, and the peace of the world."

The Euphrates and Indus lines together would, moreover, secure for us almost the control of the trade with Central Asia, enabling us to meet Russia, our great competitor in these distant fields of commercial enterprise, on more than equal terms.

But it is not on commercial considerations that I would urge the claims of the Euphrates Valley Railway. It is on imperial grounds that the scheme commends itself to our consideration. I believe that the establishment of the Euphrates route would add incalculably to our prestige throughout Europe and the East, and would do more to strengthen our hold on India than any other means that could be devised.

Although fully alive to the vast importance of the results which would accrue, not only to England and India, but to the cause of civilization generally, from the establishment of continuous railway communication between Europe and India, I cannot conceal from myself that such a project is too vast to be at once undertaken with any hope of success. But the Euphrates Valley Railway, as proposed, from the gulf of Scanderoon to the Persian Gulf, has been specially designed with a view to its ultimately forming part of a through line from Constantinople to the head of the Persian Gulf, while it is capable, also, of being, in due time, extended eastward to Kurrachee, the port of India nearest to Europe. The line from the Mediterranean to the Persian Gulf has been demonstrated to be eminently practicable and easy, which the other portions of the route between Constantinople and India are not. While capable of forming part of a through line, it would, at the same time, be complete in itself, and independent of any disturbances in Europe —the only portion, in fact, of a through line of railway which would be always, and under all circumstances, at the absolute control of this country. It would always be to this country the most important portion of any through line; and, indeed, I believe a through line could not be constructed, except at overwhelming cost, without the assistance of a port in northern Syria. It would, moreover, provide us with a complete alternative route to India, and would thus at once secure to this country advantages admitted to be of the highest national moment. It is for these reasons that, during the long period in which I have devoted myself to the advocacy of the Euphrates route to India, I have thought it expedient to urge upon our own government, and that of Turkey the special claims of that section only which would connect the Mediterranean with the Persian Gulf.

The objection that, although the Euphrates Valley Railway would afford us the undoubted advantage of an alternative, a shorter, and a more rapid means of communication with India, it would still leave a considerable portion of the journey to be accomplished by sea, and that consequently, it would accelerate our communications with the East in a minor degree only, is sufficiently disposed of by the circumstances already pointed out—that a railway from a point on the Mediterranean, at or near Scanderoon, to the head of the Persian Gulf, would naturally form part of a through line of railway from Constantinople to India, if, at a future time, it should be considered necessary or desirable to construct the remaining sections.

At the same time, it is to be observed that any possible acceleration of the journey between Europe and India, by the substitution of railway for sea transit, would be, relatively, much less in the case of those portions of the route traversing Asia Minor on the one hand, and Persia and Beloochistan on the other, than on the central section between Scanderoon and the Persian Gulf; the latter section being almost level for nearly the whole distance, and, therefore, capable of being traversed at a very high rate of speed; whereas, both in Asia Minor and Persia, the gradients would be so severe as to neutralize, in a great measure, the advantages ordinarily attaching to railway traveling as compared with that by sea. *Pro rata* to the power required, so is the distance. In other words, the proposed Euphrates Valley Railway would take advantage of precisely that portion of the route between Constantinople and India where

the greatest benefit would be derivable from the substitution of railway for sea transit, whether regard be had to the rate of speed attainable or the economy with which the traffic might be worked.

A regular mail service being already in operation on the maritime portions of the Euphrates route to India—maintained, on the Mediterranean side, by French steam packets calling at Alexandretta, and between the ports of the Persian Gulf and Kurrachee and Bombay by the vessels of the British India Steam Navigation Company—a railway of little more than 900 miles in length, from Scanderoon (or Alexandretta), on the Mediterranean, to Kowait (or Grain), on the Persian Gulf, is all that is required to secure for us the immense political and strategic advantage of a complete alternative route to India; a shorter and more rapid route than now exists, and one, moreover, which compares very favorably with the Red Sea route, both as regards climate and the facility and safety of the navigation.

Both Alexandretta and Kowait, the proposed termini of the railway, possess all the requisites of first-class harbors.

The harbor of Alexandretta is one of great capacity; sufficient according to Sir John Franklin, Admiral Beaufort, and others, to contain the whole navy of Great Britain. It is the safest harbor on the coast of Syria, and might be made available for the purposes of the railway at a very small outlay. The place is, at present, open to some objection, on account of unhealthiness; but this, its only disadvantage, might be entirely obviated by drainage, at a moderate expenditure.

With regard to the harbor of Kowait, near the head of the Persian Gulf, Mr. William Parkes, who was, at my request, by the liberality of the Indian authorities, recently enabled to examine the ports in the Persian Gulf, states, in an able report addressed to me on the subject, that "nothing could be more secure or favorable in any way" (than Kowait) "for ships of the largest size, whether to ride at anchor, or to be moored alongside a quay wall." As a place for landing and embarking passengers, mails, and cargo, even without sea works more extensive than a short jetty to bring a steam tender alongside. Mr. Parks reportes that Kowait "was superior to Alexandria, to Suez, and to Bombay, before the completion of recent improvements; while, from an expenditure of from £80,000 to £100,000, a wharf of sufficient length to berth four steamers, of £3,000 tons each, might be constructed, and the railway brought down upon it, thus placing Kowait on a par, in this respect, with Suez (as it is), Brindisi or Dover." Kowait is already one of the most important towns in the Gulf, and, according to Captain A. D. Taylor, late of her Majesty's Indian Navy, possesses more baghalahs, or boats of the country, than any other port in the Gulf which trades with India; and there can be no doubt, if it be adopted as the eastern terminus of the railway, it will, within a very short period, have an enormous trade of its own, irrespective of the through traffic passing over the railway.

As regards the route which the railway should take between Alexandretta and the Persian Gulf, it is to be borne in mind that the great and primary object of the undertaking is the connection of the Mediterranean Sea and the Persian Gulf by railway; and, the necessity of such a connection having been once established, the precise line which the railway should take, would appear to be comparatively a matter of less vital importance. I may observe, however, that, passing in the first place from Alexandretta, the proposed terminus on the Mediterranean, to Aleppo, a great *entrepot* of trade, the route from that place to the Persian Gulf having much the strongest arguments in its favor would appear to be that recommended by Felix Jones, keeping on the right bank of the Euphrates for the whole distance, beyond the reach of inundations, and passing by way of Annah, Hit (the Is of Herodotus), the holy cities of Kerbela and Nedjef (or Meshed Ali), Semárwah and Súk-esh-Sheyukh to Kowait or Grain, on the Persian Gulf. This line would not pass many miles from Bagdad. This city and the neighboring holy places of Kerbela and Nedjef, are frequently chosen by Sheeah Mohommedans as a residence, that they may be buried by the side of Hoosein, their favorite saint, whose tomb at Kerbela is the peculiar object of their veneration, and is annually bedewed with the tears of thousands. The burial-

place of Ali Nedjef, though of inferior sancity, is also held in great veneration. Pensioners of the Government of India, natives of the highest rank, frequently make Bagdad or Kerbela their adopted home; and, both from Persia and Hindustan, untold wealth has been poured into the coffers of the priests of Kerbela.

The route which I have traced from Alexandretta to the Persian Gulf—besides being, probably, the shortest line obtainable—would obviate altogether the necessity and expense of crossing the Euphrates. This line, moreover, regarded from a strategic point of view, would give the advantage of the interposition of two great rivers between the railway and an enemy advancing on the flank on which there would be the greatest likelihood of attack. The two termini, being on the open sea, would be, virtually under the guns of our ships, and the value of the island of Cyprus would be demonstrated as a *place de'arms*.

The opening up of the Euphrates route would afford an additional guarantee for the integrity of the Ottoman Empire; would tend, in a great measure, to a peaceful solution of the Eastern question; and would enable us more easily to discharge the grave responsibilities we have incurred in the virtual protectorate of Asia Minor. The proposed railway would consolidate the dominions of the Porte, by bringing the ancient Pachaliks of Aleppo and Bagdad into closer communication with the seat of Government. The grand impediment to the improvement of the Sultan's dominions is the want of means of intercommunication; and no line would promote more effectually their good government and prosperity, or do more to develop their really prodigious resources, than that which would lay open, to the energy and capital of the emigrant and merchant of the West, the extensive and fertile plains of the Euphrates and Tigris.

The cost of the most difficult portion of the railway, surveyed and estimated for by General Chesney and Sir John Macneill, and an engineering staff, was £7,500 per mile; my estimate has been higher, to make allowance for the fluctuations in the price of iron and other expenditure.

Let me recall for a moment to your notice the political inheritance said to be bequeathed by Peter the Great to his successors, in his will, whether genuine or apocryphal. "We must," says that remarkable document, which first became publicly known in 1837, "incessantly extend ourselves towards the north, the Baltic Sea, and towards the south, the Mediterranean. We must advance as much as possible twards Constantinople and India. Whoever shall reign there will be the true masters of the world. Therefore, we must face continual wars, sometimes with Persia; create dockyards and emporiums on the Black Sea; take possession, little by little, of that sea, as well as of the Baltic, which is a point doubly necessary for the success of the plan; hasten the downfall of Persia; advance into the Gulf of Persia, as far as can be done, re-establish through Syria the ancient commerce of the East, and enter into the two Indies, which are the stores of the world. When once there, we can do without the gold of England."

The policy of Russia has certainly been in accordance with the above.

The old southern boundary of Russia in Central Asia extended from the Ural, north of the Caspian, by Orenburg and Orsk, to the old Mongolian city of Semipolatinsk, and was guarded by a cordon of Cossack outposts. In 1716, Peter the Great sent a force, commanded by Prince Beckovitch, to take possession of part of the eastern shore of the Caspian. Three forts were then built, though subsequently abandoned, after an unsuccessful expedition against the Khivans. More recently, since 1834, Russia has succeeded in firmly establishing herself on the eastern shore of the Caspian, where she has now four permanent posts: Fort Alexandrovsk, Krasnovodsk, at the mouth of the Balkan Gulf, Chakishlar, at the mouth of the Attruck, and the Island of Ashurda. To the east she has crossed the Kirghis Steppe, and established herself on the Sir Daria or Jaxartes, which Admiral Boutakoff is said to have navigated for 1,000 miles in 1863. Thus the Russian frontier in Central Asia has been pushed forward, until her advanced posts on the east look down from the Tian Shan range upon the plains of Chinese Turkestan.

In Western Turkestan, also, she has gradually extended her boundary; and has annexed or subjected Tashkend, Kokan Khojund, Samarcand, Bokhara, and Khiva. In thus pursuing her career of annexation, Russia but follows the natural policy of a great military empire; being forced, moreover, as Sir John Malcolm said, by an impelling power which civilization cannot resist when in contact with barbarism. And thus is her influence established on the Oxus and Jaxartes. The Oxus, or Amu Daria, is a noble river, not easy of navigation, but it is believed, capable of being made so. It will furnish a ready means of carrying the tide of Russian annexation eastward until it finds a barrier in the Hindoo Koosh. When Russia shall have established herself along the Oxus, her position will be at once menacing to Persia and India. From Chardjuy on the Oxus, there is a road to Merv, distant about 150 miles, and from Merv a direct road runs along the Valley of the Murghab to Herat, the so-called "key of India." Merv is, historically, a part of the Persian Empire, but, in these countries, it is notoriously difficult to define boundaries with any presision. Should Russia succeed in occupying Merv—as there is too much reason to fear that she ultimately will—and in converting the neighboring tribes into friends or allies, her position would be one which would necessitate still greater vigilance on our part.

Surely in the face of such facts as these, the time has arrived when England should rouse herself from the apathy of the past, and take steps to secure the incalculable advantages which would accrue to herself and her Eastern dependencies from the opening up of the Euphrates route, which would threaten the flank and rear of any force advancing towards India.

The subject, important as it is in its bearing on the power and stability of the whole British Empire, is one of absolutely vital moment to India; but it should not be forgotten that all our Eastern possessions would participate in the benefits which would accrue from the establishment of the Euphrates route.

There is ample reason to believe that the proposed undertaking would prove remunerative at no distant date; at the same time, the results sought are far more important than those which are usually looked for in a pecuniary investment. Why should we not regard the Euphrates Railway as the French have regarded the Suez Canal? In the words of a recent writer:—

"Nations may receive much larger returns for judicious outlay than any to be commonly looked for by shareholders; for the results in material prosperity to be derived by a community from augmented facility of communication, from moral and political progress, and, above all, from an increased security for peace, far transcend in value any conceivable amount of dividends, and should be taken into account in determining as to the propriety of lending Governmental assistance in particular instances."

The general features of the projected Euphrates Valley Railway may be thus briefly summed up:—

1. It would connect the Mediterranean with the head of the Persian Gulf, between which and Kurrachee and Bombay regular communication is now maintained by a line of powerful steamers, subsidized by the Indian Government.

2. Making Kurrachee the European port of India in place of Bombay, it would save about 1,000 miles in the distance between England and India, and would reduce the time occupied in the journey by several days.

3. It would render it possible to maintain India with a smaller European garrison than is now necessary, and would thus reduce our military expenditure.

4. It would save the Government large sums, in sudden emergencies, by the facilities it would afford—and that at all seasons of the year—for the transport of troops and stores.

5. It would enable troops from England to be landed at Kurrachee in about 14 days, and in two or three days more at Lahore, Peshawur, or Delhi.

6. It would subject an enemy advancing towards the north-western frontier of India to easy attack in the flank and rear, and would render the invasion of India all but impossible.

7. It would render the resources of England so promptly available in the

East that any hostile movement directed against us, whether from within or without our Indian frontier, might thus be effectually checked before it could assume formidable proportions.

8. It would give our extensive military establishments in India a direct influence in support of our power and prestige in Europe.

9. It would give England the first strategical position in the world.

10. It would facilitate the protection of Asia Minor by England.

11. It would relieve Persia from the predominating influence of Russia, by giving her access to a port on the Mediterranean.

12. It would be easily defensible by England, both of its termini being on the open sea.

13. It would be protected, on the flank most likely to be assailed, by two formidable rivers, the Euphrates and Tigris.

14. The length of the railway from Alexandretta, on the Mediterranean, to Grain, on the Persian Gulf, would be about 920 miles.

15. The country is admirably adapted for the construction of a railway, and the cost of the line is estimated at from £8,000 to £10,000 per mile.

16. The capital which would be required would thus be under 10 millions.

The military and political value of the Euphrates line is a matter of extreme moment, and has a far more decided bearing on the defense, not only of Turkey, but of Persia, and the whole district lying between the Mediteranean, the Caspian, and the Indian Ocean, than might at first be supposed.

So long ago as 1858, Field-Marshal Lieutenant Baron Kuhn Von Kuhnenfeld, Austrian War Minister, predicted that Russia would, in future, probably, try to satisfy her craving for an open seaboard by operating through Asia:—

"She will not," says this distinguished authority, "reach the shores of the Persian Gulf in one stride, or by means of one great war; but, taking advantage of Continental complications, when the attention and energy of European States are engaged in contests more nearly concerning them, she will endeavor to reach the Persian Gulf step by step—by annexing separate districts of Armenia, by operating against Khiva and Bokhara, and by seizing Persian provinces. * *

"The most important lines which Russia must keep in view for these great conquests are—

"1. The line from Kars to the Valley of the Euphrates and Mesopotamia.

"2. That from Erivan, by Lake Van to Mossul, in the Valley of the Tigris, to Mesopotamia, and thence, after junction with the first line, to Bagdad.

"3. That from Tabrez to Schuster, in the Valley of the Kercha, where it joins.

"4. The road leading from Teheran, by Ispahan, to Schuster, and thence to the Persian Gulf. * * *

"Once in possesion of the Euphrates, the road to the Mediterranean, *via* Aleppo and Antioch, and to the conquest of Asia Minor and Syria, is but short.

"It is clear that all these lines are intersected by the line of the Euphrates, which, running in an oblique direction from the head of the gulf north of Antioch to the Persian Gulf, passes along the diagonal of a great quadrilateral, which has its two western corners on the Mediterranean, its two eastern on the Caspian and Persian Seas, and so takes all Russian lines of advance in flank.

"From this, it is evident that the secure possession of the Euphrates line is decisive, as regards the ownership of all land lying within the quadrilateral. It must, therefore, be the political and strategic task of Russia to get the Euphrates line into her hands, and that of her enemies to prevent her doing so at any cost.

"The great importance of a railway along this decisive line, which connects Antioch with the Persian Gulf, follows as a matter of course. It is the only means by which it would be possible to concentrate, at any moment, on the Euphrates, or in the northern portion of Mesopotamia, a force sufficiently strong to operate on the flanks of the Russian line of advance, and stop any forward movement. * * *

"It is true that, at first, the aggressive policy of Russia in the East will only threaten the kingdoms of Turkey and Persia; but, as neither one nor the other, nor both combined, would be

strong enough, without assistance, to meet the danger successfully, England must do so; and it is certain that she must, sooner or later, become engaged in a fierce contest for supremacy with Russia.

"The Euphrates Valley Railway becomes, therefore, a factor of inestimable importance in the problem of this great contest. Even now, the construction of the line will counteract the Asiatic policy of Russia, for it will strengthen the influence of England in Central Asia, and weaken that of Russia.

"The growth of Russia in the East threatens, though indirectly the whole of Europe, as well as the States named above; for if she were firmly established in Asia Minor the real apple of discord, Constantinople, would be in imminent danger, all the commerce of the Mediterranean would fall into her hands, and she would command the canal through the Isthmus of Suez.

"Whatever the commercial value of the Suez Canal to Central Europe, there is no doubt that it is secondary in importance to the Euphrates Railway, which affords the only means of stemming Russian advances in Central Asia, and which directly covers the Suez Canal."

Looked at in every light, historically, politically, and commercially, the proposed restoration of the ancient route of the Euphrates, throwing open the portals of the East to the commerce of the world, and to the arts, the sciences, and civilization of the West, in an interesting and noble design, fraught with consequences of the highest moment to the destinies of our race.

To plant industry and the arts where indolence and barbarism have hitherto prevailed—to hasten the day when the breath from the four winds, as foreshadowed by the prophet, will breathe upon the slain, and the dry bones will live; when "the wastes shall be builded, and the desolate land shall be tilled," and men shall say, "this land that was desolate is become like the Garden of Eden, and the waste, and desolate, and ruined cities are become fenced, and are inhabited." "So shall the waste cities be filled with flocks of men."

To accomplish this noble undertaking is the mission of England. Its fulfill ment has already been too long delayed. Another nation, as Lord Beaconsfield, some years ago, took occasion to remind us, is slowly, but surely, extending her power eastwards, and is gradually establishing a footing in military positions, from which she can at once menace our empire in the East, and diminish our power and prestige among the nations of Europe; and I would close this paper by urging my conviction, that if we continue to neglect securing the establishment of the Euphrates route under the auspicies of Great Britain, we shall speedily find that the shortest, easiest, and safest route to our Eastern possessions has fallen into the hands of our most powerful rival for commercial and political ascendancy in the East.

THE HARDENING OF IRON AND STEEL.

By Professor RICHARD AKERMAN, Stockholm.

From "Engineering."

Hardening has, as is well-known, been employed from time immemorial in order to make steel hard, but it is also a long time since it became known that the strength and tenacity of iron could be increased by the same operation. The knowledge of the effects of hardening, especially on iron, is, however, by no means so complete, and still less so generally diffused, as is desirable. This question has, besides, acquired increased interest through the Paris Exhibition, and above all from the Terrenoire exhibit of Siemens-Martin castings of extraordinary strength, and free from blowholes; and as at the meeting of the Iron and Steel Institute in Paris I ventured to give expression to the view that the reason why the strength of undrawn Martin castings may be equal to that of drawn ingot-metal of the same degree of hardness, must be sought for in the

compression induced by the hardening, I have considered it to be my duty to endeavor to explain the reasons of this in greater detail. For this purpose, however, it is necessary in the first place that we endeavor to make ourselves acquainted with the nature of hardening.

THE DIFFERENT MODES OF OCCURRENCE OF CARBON IN IRON.

Commonly the carbon occurring in iron is separated only into two principal varieties, viz., graphite and combined carbon, the latter of which is differently named—by some dissolved and by others amorphous carbon. The graphite found in iron is, as is well known, carbon in a quite distinct form, or, in other words, only mechanically incorporated with the iron, and it is accordingly obtained as such when pig iron is dissolved in an acid. The so-called combined carbon, on the other hand, when the iron is dissolved in boiling hydrochloric acid, escapes as carburetted hydrogen if proper attention be given to the dissolving process, so that the boiling commences almost immediately after the addition of the iron to the hydrochloric acid, and is continued uninterruptedly for a sufficient length of time without access of air. If the iron, again, be dissolved in cold hydrochloric acid, which is only warmed after a little, a part of the so-called combined carbon also in general remains as a black residue, and this is apt to be the case in a still greater degree if the air has had readier access, for in that case it appears that humus-like substances may be formed by its action on a part of the combined carbon. More or less of the combined carbon remains as an undissolved residue according to the different ways in which the solution is carried on, and its being completely driven off can be reckoned on with certainty, only provided the solution proceeds in acid which is brought immediately to continuous boiling, without access of air in the way first described. M. Caron, and after him Herr L. Rinman, have, moreover, further discovered that the quantity of carbon remaining undissolved when steel is dissolved in cold hydrochloric acid may be very different, according as the same steel was differently treated before dissolving. Thus, raw steel undrawn on being dissolved in this way gives a much larger residue of undissolved carbon than the same steel when rolled, and the latter more than when it is drawn out under the hammer. Finally, this residue of carbon approaches to none at all in the well-hardened steel. If this well-hardened steel be heated anew, it yields again a large residue of undissolved carbon, and this in a degree proportioned to the duration and intensity of the heating.

These facts undoubtedly indicate that the so-called combined carbon does not occur in the iron always in the same way, and as we have every reason to suppose that the carbon was in more intimate union with the iron in the same proportion as it was, on the solution of the iron being carried out in the same way, the more completely driven off as carburetted hydrogen, and the less it was separated as carbon, it appears that we may conclude from these circumstances that drawing, and, above all, hardening, cause a more intimate union between the iron and the carbon, this union, on the other hand, being again relaxed by the renewed heating and subsequent slow cooling of the iron. It thus appears that the carbon commonly called combined ought properly to be divided into two kinds: viz., first, the carbon most intimately combined with the iron, which we, in accordance with Rinman's proposal, shall call hardening-carbon, inas much as it characterizes the well-hardened steel; and, further, the carbon incompletely combined with the iron, which may be said to be in a sort of passage to graphite, and which Rinman called cement-carbon, because it occurs in largest proportion in the undrawn raw or cement steel.

If we now inquire what the circumstances are on which it depends whether more or less of the so-called combined carbon in a malleable iron or steel exists as hardening or cement-carbon, it immediately appears that the latter is changed into the former by a heating to a red heat, succeeded by a violent forcing together, continued until cooling is almost complete; while hardening-carbon, on the other hand, is changed into cement-carbon by long-continued heating, followed by slow cooling without extra compression. In order to show that iron and carbon may be combined by pressing together more easily than other-

wise, Caron, upon an anvil covered with charcoal in fine powder, hammered out quickly a strongly heated piece of iron, which in this way was steeled on the surface, while another piece of the same iron heated as strongly, which was imbedded in similar charcoal powder, and allowed to cool in it without hammering, d.d not show the least sign of steeling.

In the case of strong hardening of hard steel, we have the most powerful compression, for the rapid cooling produces a great difference of temperature between the outer and the inner layers of the piece, the more cooled exterior layers compressing the interior with greater force in proportion, partly as the latter are expanded by being more strongly heated, and partly as the limit of elasticity of the substance is high, so that there is not too great a loss of the compressing force by the extension of the exterior layers. Again, that hammering favors the conversion of cement-carbon into hardening-carbon, or the more intimate union of the carbon with the iron in which it occurs, more than rolling, may at least occasionally to some extent be attributed to the more powerful compression exerted by the hammer, but still more to the circumstance that the iron or steel, when the rolling is ended, commonly has a far higher temperature than when it has been drawn out under the hammer. For if the iron or steel be still red-hot when the drawing is finished, a part of the carbon converted into hardening-carbon, or more intimately united with the iron during the compression to which it has been subjected, may be again changed into cement-carbon during the succeeding slow cooling.

There is thus a very complete correspondence between the occurrence of hardening and cement carbon and their mutual conversion in malleable iron and steel on the one side, and the relations of the combined carbon and the graphite in pig iron on the other. It is, however, not improbable that the so called combined carbon may occur in pig iron also in two ways. A grey but not too siliceous pig may, as is well known, be converted into white pig iron by melting, followed by sufficiently rapid cooling, as by casting in thin plates in a form adapted for rapid cooling; or, if the rapidity of cooling be not sufficiently great in this way, by so-called granulating in water, or some yet more rapid mode of cooling. On the other hand, a white pig, somewhat rich in carbon, but not containing too much manganese or sulphur, may, by melting and superheating, followed by casting in a heated mould which cools with sufficient slowness, be converted into gray pig iron. But in order to change to gray a white pig of the nature described above, it is quite unnecessary to remelt it; for the greater part of its combined carbon may also be converted into graphite merely by a sufficiently long-continued heating to a strong yellow heat, air and other oxidizing substances being excluded.

Graphite as such cannot be found in the molten pig, for it must then, in consequence of its comparatively low specific gravity, rise to the surface of the bath of pig iron, and form a deposit there, which, as is well known, happens very frequently; but in such a case this graphite is found not in, but upon, the pig iron. It thus follows that the graphite to be found in solidified pig iron has not been able to separate itself sooner than immediately after solidification, and whether a pig becomes gray or white depends, besides the presence of other substances in the iron, just upon the rapidity of cooling at or immediately after solidification. But this again depends greatly on the degree of superheating of the pig iron when it is cast in a certain form, for the more super heated the pig iron then was, so much more heat has the mould been able to take up before solidification commences, and the slower consequently is the suc ceeding cooling. Thus also it is only by a long-continued heating to a tempera ture approaching somewhat closely to the melting point of pig iron that the white pig may, without remelting, be converted into gray; but if the temperature be raised still further, so that fusion commences, the graphite which has been separated from the iron is again dissolved in it, for otherwise it would naturally rise to the surface. It is on this, too, that it must depend that the fusion point of the gray pig is only about 100° C. higher than that of the white, and thus so incomparably lower than the fusion point of steel or mallea-

ble iron, which have the gray pig's content of combined carbon, but altogether want its graphite.

As in pig iron, with strong and long-continued heating, carbon is separated in the form of graphite, so heating, followed by slow cooling, favors the formation of cement-carbon in steel. On the other hand, by the rapid cooling of the molten pig and the violent contraction thus occasioned, the content of combined carbon in the iron is increased, and in the same way a rapid cooling or violent compression otherwise attained causes in the graphite-free steel a more intimate union of the cement-carbon with the iron, or its conversion into hardening carbon. The difference is only that the mutual conversion of cement and hardening carbon may begin at a comparatively low temperature, while the conversion of graphite into combined carbon and the reverse process can only take place at a temperature approaching pretty close to the melting point of pig iron; for after a gray pig has cooled to a red heat, the final cooling may be as rapid as possible, without the content of graphite being thereby diminished; and in the same way, at a temperature no higher than a red heat, a white pig cannot be converted into a gray.

The properties of a pig iron, almost free from other substances than carbon, are properly dependent on the content of combined carbon, and graphite exerts an influence upon it only so far as it diminishes the continuity of the iron molecules, and thereby lessens the strength; to which may be added that, as we have seen, it may, by the use of proper methods, be converted into combined carbon, which then exerts its usual great influence upon the iron. Just the circumstance that the important fact now stated is generally overlooked is the reason why we so often meet with the incorrect statement, that the influence of carbon on pig iron is quite different from its action on malleable iron and steel. It is easy to prove the contrary if we distinguish properly in pig iron between the combined carbon and that which is only mechanically incorporated as graphite, which, of course, ought not to be included in the calculation in any higher degree than as stated above, if we wish to form a judgment of the properties of pig iron as dependent on its content of carbon.

As the cement carbon cannot, as has been shown above, be so intimately combined with the iron as the hardening carbon, but approaches in some degree to graphite, the supposition is easily arrived at, that the cement-carbon cannot have so great an influence on the properties of iron as the hardening carbon; and there are very distinct indications of this, as will be seen from what follows, but until hardening and cement-carbon can with certainty be distinguished, and some method has been discovered of quantitatively determining each of them, it is, of course, still too early to say anything with certainty on this point. In the near future the requisite light will certainly be thrown on this point also, and we will then probably see that some of the great changes in iron and steel which have been induced only by different methods of treating the same material, are caused by the alterations in the proportions between hardening and cement-carbon brought about by the method of working.

Methods of Hardening.—Proceeding now to the hardening, we find that experience has sufficiently shown that its effect mainly depends upon the content of combined carbon in the iron, upon the differences of temperature between the iron or steel and the hardening fluid, and further on the rapidity of the cooling. The last-mentioned, again, is dependent on the quantity of the hardening fluid, its specific gravity, power of conducting heat, specific heat, boiling-point, and heat of vaporisation. Of the four liquids, mercury, water, oil, and coal tar, therefore the first-named hardens much more powerfully than oil, and oil more powerfully than coal tar. Further, the hardening power of water is altered not only by differences of temperature, but also by the addition of different substances which change its properties in the respects just mentioned. Finally, the rapidity of cooling, so important for the degree of hardening, is also dependent on the way in which the piece is held down into the hardening fluid. For if it be kept still in a hardening fluid of low specific gravity and small conductivity and specific heat, the quantity of the hardening fluid is not of the same import-

ance as if the piece be unceasingly moved about in it; but in the latter case the cooling of the piece is apt to be unequal, inasmuch as by the moving about the front parts are cooled somewhat more rapidly than the back ones. This is also the case if by hardening in running water we make the quantity of the hardening fluid, so to speak, unlimited. The front part of the piece, or that which is termed up-stream, is then, of course, cooled most rapidly; and in order in such a case to attain an even hardening, it is necessary to turn round the piece rapidly and unceasingly.

The layer of steam which, in the case of hardening in a substance so easily converted into vapor as water, is formed around the warm piece is an obstacle to the cooling along with the degree of hardening which is dependent upon it; but if care be taken that in one way or another the steam be easily and rapidly carried away as it is formed, the rapidity of cooling, on the other hand, on account of the great heat of vaporization of water, is very considerably promoted by this conversion into vapor. Small pieces, therefore, are also very well hardened in water dust finely distributed by means of a stream of air or steam; and the highest degree of hardening may, according to Herr Jarolimek, be attained in this way with so moderate a quantity of water that all the water dust which comes in contact with the warm piece is brought by it into the form of steam. These influences, exerted by the formation of steam, must also be taken into consideration when, in order to attain an inferior degree of hardness, warm water is used instead of cold. It cannot accordingly be denied that there are many factors exceedingly difficult of calculation which exert an influence on the speed of cooling, and thereby on the degree of hardness. Nor is it much to be wondered at that mistakes are readily committed in hardening, and that great practice is required in order to be able confidently to reckon on a certain effect; and, finally, that a workman accustomed to hardening considers that only a single method which he has been in the habit of employing can be used for a certain purpose, while another equally skillful workman can only attain the same result by a method essentially different.

It further appears that the rapidity of the first cooling, from the 600 deg. to 700 deg. C., to which steel has commonly been heated, to 300 to 400 deg. C., has a manifold greater influence on the degree of hardness than the succeeding cooling. Thus, the just mentioned Herr Jarolimek has shown that steel wire may be very well hardened both in watery vapor and in molten tin, lead, and even zinc, though the last-named metal does not melt under 400 deg. C., while the cooling of the same steel wire from 300 deg. or 400 deg. to 0 deg. C. does not cause any true hardening, however rapidly it may proceed. In order that steel wire may be hardened in this way, it is not, however, allowed to remain any considerable time in the molten bath of metal, for, by long-continued heating following such a hardening the degree of hardening is afterwards diminished more and more. If it be taken out again after being dipped in the bath for quite a short time, and afterwards allowed to cool in the air, the degree of hardening for small articles is equal to that attained by ordinary hardening with the tempering following upon it.

The Effects of Hardening.—Of the effects produced by hardening, it was in old times mainly the hardness on which attention was fixed, and from this is derived the old saying that a substance does not take hardening if it do not thereby become so hard that a common file can no longer exert any noteworthy influence upon it. From time immemorial a distinction has also been made between iron steel in this way, that the former, with common hardening in water, is not hardened in the sense just indicated, while steel, on the contrary, is hardened. Since the Bessemer process came into use, however, the old idea of steel has had too often to give way to the desire to denote with the appellation steel all such iron is in the finally refined state has been completely fused, whether it "takes temper" or not. In accordance with the proposal unanimously made by the International Committee, nominated at the Philadelphia Exhibition, Germany, Austria, and Sweden have universally retained the old idea of steel, at the same time, however, that an exact distinction is made between those varieties of iron and steel which, in a finally refined state, have been completely fused and those that have not been so,

the former being named ingot iron and ingot steel, and the latter weld iron and weld steel. In Great Britain, the United States, France and Belgium, on the other hand, there has not been the same unanimity, and hence arises the lamentable uncertainty which now often prevails, when, for instance, a soft steel is spoken of, for by this one may understand a soft ingot iron, which, by hardening, never becomes properly hard, and another a true steel, which, however, is not harder than that it just "takes temper."

We sometimes hear it brought as an objection against the old way of distinguishing between iron and steel that it is difficult to determine whether a piece, after common hardening in water, is to be considered as having taken true hardening or not. But such a reason is in fact quite unwarranted, because, according to the old view, only the varieties approximating most closely to each other of the hardest iron and the softest steel can be mistaken for each other, and such a mistake is indeed of little importance when compared with the great mistake just referred to of soft iron for soft steel. If it be wished wholly to avoid the possibility of making mistakes between hard iron and soft steel, this even ought to be attained very easily by the method of determination, in which a sharp edged splinter of a certain mineral —felspar, for instance—scratches iron, although, after being heated to a moderate red heat, it has been suddenly cooled in cold water, while steel, after similar treatment, cannot be scratched by the same material.

The substance which exerts the greatest influence on the increase of hardness by a certain hardening process is the content of combined carbon in the iron. Iron completely free from carbon is, even after hardening in mercury, as soft as before, and an otherwise pure iron, with at most two-tenths per cent. carbon, does not become very much harder by hardening; but, on the other hand, as the content of carbon increases, the difference in the degree of hardness before and after hardening increases more and more, so that the boundary line between iron and steel lies in general at a content of carbon of about 0.4 per cent., this depending, however, upon the iron's content of certain other substances, which, as we shall soon see, also exercise some influence on the degree of hardness.

In the closest connection with the increase of the hardness, stand the raising of the limit of elasticity, and the breaking strain or ultimate tensile strength and the diminution in ductility. Unfortunately the researches that have been carried out regarding these points are not yet numerous enough to enable us with figures to express completely all the changes in these respects which are caused by hardening in iron and steel with different contents of carbon, but sufficient experiments have already been made to give us somewhat satisfactory ideas on this point. A comparison between the Tables I., II. and III., shows that the effect of hardening is in general less in the case of weld iron, loose or open in its texture, than in that of the dense or compact ingot iron; but in proportion as the former even is denser or freer of cinder, hardening has a greater effect upon it, as is shown by a comparison both of the more compact Lesjöfors iron with the other sorts of iron refined in the open hearth, and of the more compact Surahammar with the other sorts of puddled iron, all in Table II. In order to augment considerably the strength of ordinary puddled iron, the French iron manufacturing company, La Compagnie de l'Horme, increases the hardening power of water by adding to it sulphuric acid the cooling effects of water is thereby raised, and thus also its hardening power; but in order to prevent the corrosion and rusting of the iron, it would be advisable to endeavor to attain the same result in some other way, as by the addition of some salt that would have less corrosive action upon the iron. The following little table shows the mean results of breaking tests of puddled iron from Buère, part unhardened and part hardened in the dilute sulphuric acid.

"Fer Ordinaire."

Unhardened.		Hardened in Dilute Sulphuric Acid.	
Breaking Weight.	Elongation per Cent.	Breaking Weight.	Elongation per Cent.
kilo. per sq. mm.		kilo. per sq. mm.	
38	17.5	41	20

"Fer Fin."

Unhardened.		Hardened in Dilute Sulphuric Acid.	
Breaking Weight.	Elongation per Cent.	Breaking Weight.	Elongation per Cent.
kilo. per sq. mm. 37.7	23.8	kilo. per sq. mm. 48.2	14.8

The ductility, so far as it is indicated by the elongation and contraction of the area of fracture, is indeed generally diminished by hardening even in the soft varieties of iron; exceptions, however, are to be found to this rule, and this appears to be specially the case with the more phosphoriferous iron, the resistance of which to breaking, elongation, and contraction of the area of fracture, may even be increased by hardening, as for instance is the case both with the iron from Aryd made by refining lake ore pig iron in the open hearth, and with the most phosphoriferous of the varieties of puddled iron from Buère which have just been mentioned. This is, besides, confirmed by several other facts; as for instance that Martin iron with 0.15 per cent. phosphorus can stand much severer bending tests after hardening than in an unhardened state.

In order to obtain a somewhat satisfactory idea of the ductility of a substance, we ought not, however, to fix our attention exclusively on the breaking elongation and the contraction of the area of fracture, but also to pay due regard to the ratio of the limit of elastic strength to the breaking weight. For the smaller this ratio is, the greater force beyond the limit of elasticity, can the substance resist without fracture, and tougher accordingly it is. To this ratio more attention ought doubtless to be given than is commonly the case, the rather because it is possible to get very different values for the limit of elasticity of a certain substance, according to the different ways in which the breaking tests are carried out. For the more it is sought to carry out the tests so that they shall give a high limit of elasticity, the greater, and therefore the more disadvantageous for the ductility, does the ratio of the limit of elasticity to the breaking weight become; and for those who lay sufficient weight on this point, there is a self-acting retribution if, in order to be able to boast of a high limit of elasticity, it is determined in some unfair way, as is sometimes the case.

In this connection there is also, perhaps, reason to point out another too common impropriety in breaking tests, viz., the different ways in which the breaking elongation is estimated. This elongation is of course greatest in the neighborhood of the place of fracture, where the sectional area is most diminished. The most thorough-going method, therefore, is to exclude the whole of the elongation in the neighborhood of the place of fracture, as Herr Styffe has done (see Table II.) in the case of the hardened samples, and limit attention wholly to the much smaller percentage of elongation which the other parts of the bar have undergone. In this way there are of course obtained very small percentages of elongation, which cannot be compared with those found when the elongation at the place of fracture is included in the calculation. On the other hand, the advantage is gained by the first described method that we are somewhat independent of the length of the test bar, which by the other method is by no means the case. For it is certain that the longer the test bar is, the less influence will the elongation at the place of fracture have in the calculation of the whole percentage of elongation. The shorter the test bar is, on which the greater elongation at the place of the fracture is divided, the more considerable on the other hand does its influence become, and thus the greater or more advantageous does the percentage of elongation appear. It ought, therefore, when, as is commonly the case, the elongation at the place of fracture is included in the calculation, never to be left unstated on what length of test bar the elongation percentage is reckoned; but the sectional area of the bar ought besides to be included in the calculation, for the larger it is, the greater is the elongation of a certain iron in the neighborhood of the place of fracture.

In order to be able to boast on paper of a comparatively great percentage of elongation, it is only necessary to carry

out breaking tests on short and thick bars, and such tricks are, in consequence of the too common ignorance of purchasers of iron, unfortunately not at all uncommon. However, there is some help to be had even in this respect by giving proper attention to the ratio of the limit of elasticity to the breaking weight. For if this ratio be large, while the length and sectional area of the test bar are not stated, we have reason to suppose when the breaking elongation notwithstanding has been stated to be comparatively large, that it has been determined in a too favorable manner, and that the ductility of the material is, therefore, in fact not so great as would appear from the percentage of elongation alone. It is clear from this that a closer correspondence in the dimensions of test bars is very desirable, but so long as great variations occur in them, the greatest caution, as has been already observed, must be used in comparing statements from different testing establishments, which is also to be observed in making comparisons between the tables given with this paper.

If we now inquire what influence the hardening has upon the oft-mentioned ratio of the limit of elasticity to the breaking weight, we find in Table I., that the comparatively pure ingot iron has by hardening become much tougher, for although the limit of elasticity has been thereby increased on the average of 30 tests of 15 different sorts of Bessemer iron from 20.8 to 25.7 kilogrammes per square millimetre, the breaking weight has increased in a still greater degree, the consequence of which is that the ratio of the limit of elasticity to the breaking weight of these pure sorts of Bessemer iron has been diminished by the hardening on an average from 0.502 to 0.398. So great an increase of toughness by hardening, however, is by no means everywhere common, but is perhaps mainly dependent on the purity of these Swedish varieties of iron being greater than is common in other countries. On the contrary, the ratio of the limit of elasticity to the breaking weight appears to be in general somewhat increased by hardening. This is the case among others with the tests given in Table III, of drawn Martin metal, excepting, however, the most phosphoriferous, whose toughness was increased by hardening, while the ratio of their limit of elasticity to the breaking weight was diminished from 0.627 to 0.559.

The last-mentioned fact yields a further proof both of a special beneficial influence that the hardening has on the phosphoriferous iron, to the probable causes of which we shall return below, and of the importance of giving proper attention to the ratio of the limit of elasticity to the breaking strain, for in the unhardened metal the three most phosphoriferous samples in the Table referred to show the highest figures for the oft-mentioned ratio, but at the same time these are the only ones in which it is diminished by hardening. The other corresponding figures in this Table have, on the contrary, been increased. In other words, the toughness of the more phosphoriferous, like that of the purest iron, as shown in Table I., has been increased by hardening, but the toughness of the others, and especially of the steel, has been diminished by the same process. This diminution in toughness is, however, not very noteworthy in the case of the iron, the rather because it depends more on a special raising of the limit of elasticity than on any deficiency in the increase of the ultimate tensile strength, and the strength of these sorts of iron may nevertheless be said to have been considerably increased by the hardening.

Table III. further confirms the long-known fact that a large content of manganese is apt to make the steel go in pieces in hardening.

Hitherto we have only considered the influence of hardening upon iron, but if we now proceed to investigate its action on steel, we find that it is shown chiefly by an increase in its hardness and a diminution in its ductility greater in the same proportion as the steel is richer in carbon and the hardening fluid employed is more powerful in its action. At the same time that steel with an increased contents of carbon, becomes through a certain hardening all the harder, it becomes thus at the same time more brittle; and in the closest connection with this is the fact, that in the hard steel rich in carbon the limit of elasticity is increased by hardening much more than the ultimate tensile strength, so

that these in the strongly hardened hard steel even coincide. Provided the method of hardening is adjusted to the degree of hardness of the steel, so that it is less powerful in the same proportion as the content of carbon in the steel is greater; it may, however, be asserted that the breaking weight is increased by hardening, even in the case of steel; but if the hardening be too strong, the ultimate tensile strength of hard steel is thereby diminished quite rapidly, as Table II. clearly shows; or the steel breaks in pieces of itself either during the hardening or a short while after, as is seen in table III.

It is, as is well known, on account of this brittleness or deficient ductility that the hardened steel is usually tempered or heated to 200 deg. or 300 deg. C., for thereby its ductility is somewhat increased, but its hardness at the same time also diminished. This is the case most of all with the outer layer, which of course is that which it is desired should be hardest, and to avoid this and the trouble and loss of time connected with the process just mentioned, the hardening itself is sometimes instead so modified that its effect is equal to that of a more powerful hardening, followed by tempering. For such a method, however, more than common skill and practice are required, and it is therefore comparatively seldom used. For attaining this end there is sometimes used a less powerful hardening fluid, and sometimes a warm instead of a cold fluid, and sometimes the piece is held only a short time in the hardening fluid, and is taken out while it is yet warm in its interior, and allowed finally to cool in the air. Further, the material may, for this purpose, be heated more gently, but it must be kept in mind in connection with this that a less heat than a little red heat (cherry red) in general does not induce any proper hardening; and, on the other hand, that tool steel cannot in most cases be heated to a higher temperature than that just indicated without running the risk of becoming by hardening quite too brittle. It is thus properly only for soft steel and iron that the degree of heating can be varied to a greater extent, but it holds good specially for the latter, and, above all, for weld iron, that the temperature must be considerably higher than for hard steel, if the proper action of hardening is to be attained.

The more strongly and the longer that the iron or steel after hardening is again heated with slow cooling supervening, the more completely are the effects of hardening removed; and care ought, therefore, as is well known, to be taken in tempering; but here we have, however, a good help in the different colors of tempering which follow one after the other.

On the appearance of fracture also the hardening has an influence, the grain becoming finer.

THE INTIMATE CAUSES OF HARDENING.

After having now discussed in detail the effects of hardening on the different varieties of iron and steel, we shall now, in conclusion, endeavor to ascertain the intimate causes of these effects. That they increase with the rapidity of cooling, and thus are a consequence thereof, has been already shown, but the question is how the rapidity of cooling can produce such effects. The hypothesis that is still most common is that which assumes that a rapid cooling gives us the *status quo*, or the state into which the substance was brought by the heating which immediately preceded the rapid cooling, and the action of the hardening would in such a case only be a result of the heating itself, inasmuch as the rapid cooling only, so to say, fixed the warm condition, or, in other words, made it possible for the substance, even in a cold state, to show itself as it was during the heating. During slow cooling, on the other hand, the molecules would have opportunity to group themselves in a more crystalline manner, and hence the coarser grain. But if the molecules can move about in this way during the cooling, they may well do so to a still greater extent at the highest temperature to which the substance has been heated, for this grouping of the molecules is rendered possible just by the softening to a greater or less degree which the heating causes in the iron, and the softening is naturally greater the higher the temperature is.

As it has now been discovered that various crystallized precious stones may be artificially produced, and that the main condition for this is to keep the

requisite raw materials uninterruptedly for a long time at a certain high temperature, and afterwards allow them to cool slowly, but that this object, on the other hand, can certainly not be attained by merely heating the materials quite hastily to the same temperature, and afterwards allowing them to cool slowly, the time appears also to be come for abandoning the view that the slow cooling from a certain degree of heating produces a disposition to crystallization that did not exist at the highest temperature. Another striking proof of the unwarrantable nature of this view also is to be found in the fact already stated, that a white pig, poor in manganese and sulphur, but somewhat rich in carbon, may, by sufficiently long-continued heating to a yellow heat, be converted without fusion into gray. Such a change, on the other hand, is not produced merely by a short heating to a yellow heat with slow cooling supervening, and it is therefore clear that it is not so much the slow cooling as the continuous intense heating which brings about the molecular change in question.

The too common view of the *status quo* cannot thus in this case be maintained, but instead a satisfactory explanation of the phenomena of hardening appears to be obtained by supposing that the compression on forcing together of the substance dependent on the rapidity of cooling produces the changes in it which are brought about by hardening. The reasons for the correctness of this view are, as we shall now see, many and striking.

That, first of all, a violent compression must in such a case take place is self-evident, for we have now to do with a body heated from without, which, therefore, at least when the heating has not been of all the longer duration, is apt to be warmer in the outer than in the inner layers. When now this body by dipping in a hardening fluid, or in some other way, is exposed to a rapid cooling action from without, the outer layers are cooled first, and the difference of temperature between the outer and the inner layers is greater the whole way through in the same proportion as the method of cooling is more powerful. And the cooling is accomplished by compressing or forcing together, and the more the outer layers have been cooled in proportion to the inner, with the greater compressing force must the former work upon the latter, which by their resistance react upon the outer layers.

The compressing force is, however, by no means exclusively dependent on the rapidity of cooling, but also on the compactness of the material. For the smaller this is the more readily does the material allow itself to be compressed, and the less accordingly becomes the resistance which the interior develops against a certain compressing force, so that no great resistance is ever experienced in such a case. In this way is explained the fact, which has already been pointed out, that the effect of hardening is greater on the compact ingot-iron than on the weld-iron, which is looser in its structure. Further, the compressing force is naturally in a very high degree dependent on the limit of elasticity of the material, and the smaller this is the more easily are the outer layers stretched by the resistance of the inner, and the smaller, therefore, is the portion of the contracting force which can be made available as actually compressing. All substances which in iron increase its limit of elasticity ought, therefore, to have an influence on its power of hardening; a fact which has also been confirmed by experience, inasmuch as not only carbon, but also manganese, silicon, and phosphorus have shown themselves to have some influence in this respect. The action of the other substances, however, upon the degree of hardening is limited in comparison with that of carbon, and the explanation of this appears, as has already been pointed out, to lie mainly in the more intimate union between iron and carbon, which a violent compression produces. As the union between these substances becomes more intimate, the influence of the content of carbon on the iron also becomes greater, and it is, as we shall now see, just an increased exertion of the influence of the carbon on the iron that is attained by hardening.

The limit of elasticity and ultimate tensile strength of the unhardened iron increase, as we have long known, and as Table II. shows, with its content of combined carbon, not, however, to an unlimited extent, but in the graphite-free

iron series (malleable iron and steel) to a content of carbon of about 1 per cent., higher in proportion as the steel is purer or consists more exclusively of iron and carbon, but on the other hand lower in proportion, as along with these it contains other substances which have an influence on its properties. Within the graphite bearing iron series, or pig iron, the limit of elasticity and the ultimate tensile strength increase together with the content of combined carbon, but to a somewhat higher limit, or a contents of carbon of about 1.5 per cent. The reason of this difference again clearly is, that the more combined carbon a pig iron smelted from a certain furnace charge contains, the less is in general its content of graphite, and the less accordingly is the weakening action which it produces by separating the molecules of iron. When the content of combined carbon exceeds figures which under various circumstances approximate more or less closely to these limits, the tensile strength diminishes.

If we now compare with this the influence of hardening as stated above, it immediately appears that it only still further increases the degree of the properties just mentioned as dependent on a certain content of combined carbon, quite as if the content of combined carbon had been increased by the hardening; and in the most complete correspondence with this stands the fact that the ultimate tensile strength is not continuously increased by the hardening; but if steel with a large content of carbon be strongly hardened, the limit of the increase of tensile strength is exceeded, as is clearly shown by Table II. The correspondence between the action of hardening and of a larger content of carbon is thus manifest in this case also. The diminution of the tensile strength by a too strong hardening of a highly carbonaceous steel is, however, much more rapid than the corresponding decrease in consequence of the content of carbon being too large in the unhardened steel (see the highly carbonaceous kinds of steel from Högbo and Wikmanshyttan in Table II.), but this difference is easily explicable by the great tension which a strong hardening must produce in the highly carbonaceous steel. When a hard steel is too strongly hardened, the larger pieces in particular readily break in pieces of themselves, which again is a natural consequence of the fact already mentioned, that the limit of elasticity in this case nearly coincides with the ultimate tensile strength, and therefore when the resistance of the inner layers against the contraction of the outer becomes so strong that the limit of elasticity is exceeded, fracture of the hard steel readily takes place instead of the extension which would have taken place in the outer layers of a less hard steel.

The same correspondence between the influence of hardening and an increased content of carbon also prevails in respect of ductility and hardness and the fineness of the grain. The first of these properties diminishes, and the two others increase, as we all know, with the content of carbon, and corresponding changes are produced, as we have seen, by hardening.

That the effects of hardening are produced by the compression caused by rapid cooling is further confirmed by the correspondence between them and the influence of cold working. For, as is well known, the limit of elasticity and the breaking strain and fineness of grain are increased by powerful mechanical treatment when the iron is in a cold or only slightly warm state, as, for instance, both by wire-drawing and rolling and hammering in a cold or slightly warm state, while the ductility on the other hand is diminished. In the same way the rolled iron commonly has a lower limit of elasticity and less ultimate tensile strength but greater ductility than the hammered, inasmuch as hammering in general is continued to a much lower temperature than is common at the close of rolling; but by sufficiently strong ignition all the changes produced by cold working can, as we know, be again taken away, and the same, as we have seen, is the case with the corresponding changes caused by hardening.

Another proof that the effects of hardening depend on the oft-mentioned compression is afforded by the behavior of burnt iron in hardening. Burnt iron, as is well known, is the name given to an iron which, through to long continued

or strong heating, has had the opportunity of assuming a crystalline texture, with the brittleness which accompanies it on account of diminished cohesion of the crystals. The disposition to such a crystalline segregation is less in proportion as the iron is both more mixed with cinder and freer from certain substances; but the more carbon, and in particular the more phosphorus, it contains, the greater is the liability of the iron to be burned, and the more care ought, therefore, to be taken with the heating, if it is not, in consequence of this distribution into crystals, to fall in pieces utterly, or at least crack, as soon as the drawing begins. An iron practically free from these substances can, without danger of burning, be heated to the strongest welding heat, but with an increase of carbon in the iron all the more care, as has been already said, must be observed in the heating, and this is rendered necessary in a much higher degree by an increased content of phosphorus in the iron. So long as the content of carbon in the iron is quite small, however, this detrimental influence of phosphorus is still rather limited, more particularly if the iron contains at the same time a good deal of manganese; but the greater the content of carbon in the iron, the more is the detrimental influence of phosphorus increased, and the first requisite of a really good steel is, therefore, that it contains as good as no phosphorus.

An iron whose disposition to burn is so great that this detrimental change cannot in general be avoided, has from old times been called "old short," from the brittleness caused by its crystalline texture. But in this connection it must be kept in mind that the disposition to burn, increasing with the content of phosphorus, is not only counteracted by the presence of manganese and the absence of carbon, but also that the iron molecules in the puddled iron are intercalated with layers of a fine interspersed cinder, which is unfavorable to the formation of the coarse crystals which cause the brittleness. A certain content of phosphorus is, therefore, not so detrimental to the puddled iron, loose in its texture and mixed with cinder, as to the cinder-free ingot iron, and if by the adoption of a suitable treatment the production of even the least sign of crystalline texture be prevented, a content of phoshorus rising to two-tenths per cent. does no great harm to the iron so long as it is in the non-crystalline condition just mentioned; but the difficulty is just to avoid the crystalline texture in the phosphoriferous iron, and, if success is attained in this, to prevent the formation of crystals in the case of a possible future reworking of the iron in a warm state.

Now, whether an iron, which from one cause or another has a tendency to burn, becomes after a certain heating, burned or not, depends mainly on the degree to which it is afterwards drawn out; for the more an iron, which when heated has begun to be crystalline, is afterwards drawn out in a warm state, the less is the danger that the crystalline texture will remain in the fully drawn iron. In this way it is explained why a greater degree of drawing out, and thus also larger ingots, are requisite for a more than for a less phosphoriferous iron. If however, an iron, after a certain heating, followed by drawing, still appears to be coarsely crystalline or burned, this burning can frequently be removed by heating the iron anew to a certain welding heat, properly adjusted to its contents of carbon and phosphorus, succeeded by a new drawing out; but we must not, however, make ourselves too sure that we can in this way always remove the burning or cold-shortness.

In complete correspondence with this, experience has shown that burning can be removed by a corresponding heating, followed by hardening instead of by drawing; and this circumstance affords a new proof of the correctness of the view, that the effects of hardening must depend on the compression caused by the contraction, as it, like the drawing out, can remove the crystalline texture. In close connection with this, doubtless, also stands the circumstance that has already been pointed out, that the hardening of an iron which contains much phosphorus, but little carbon can even increase its ductility, for the somewhat crystalline texture of a phosphoriferous iron may be destroyed by hardening, whereby again its ductility is greatly increased.

To the older observations which we have noticed above, there has lately been

added a new experience, which further confirms the correctness of the view that the effects of hardening depend on the compression caused by the contraction. The experience now referred to, viz., that ingot metal free from blowholes can, without drawing, and merely by hardening, followed by a new heating to redness, become quite equal to ingot metal that has been drawn out, is indeed not so altogether new, for it was communicated eleven years ago to the Technical Society of St. Petersburg, by Herr Chernoff, who, however, sought to explain it in a way that did not appear satisfactory to me. It is, however, first through the splendid efforts made at Terrenoire to produce castings of Martin metal equal in quality to drawn ingot metal that the fact in question has become more generally known and has attracted due attention.

Table VI. shows to how great an extent not only the limit of elasticity and ultimate tensile strength, but also the ductility of ingot metal, are increased by its being drawn out while warm; but if we compare with it the results from Terrenoire, given in Tables III. to V., we see that improvements quite as great can also be attained without drawing, merely by proper heating followed by hardening and a renewed heating in order to increase the ductility. The explanation of this appears to me evidently to be that the contraction from without inwards, caused by the cooling in this as in the cases formerly described, brings about a compression similar to that caused by drawing with the effects which follow it; but it is a fact that in proportion as the content of carbon is greater, the ductility, when this method is employed, is less than in drawn metal with the same content of carbon, for the undrawn ingot metal becomes, by hardening alone, almost the same as that which is hardened after being drawn. If the hardening, however, be followed by a new heating to redness, not only the brittleness but also the excess in the limit of elasticity may be taken away, so that only so much remains as would have been produced by drawing alone, and the undrawn casting is now comparable with ingot metal of the same composition, which has been drawn, but not hardened.

It is, at least if the content of manganese be not all the greater, however, only when the percentage of carbon exceeds 0.3 that the ductility suffers through hardening any loss endangering the strength of the material, and it therefore appears probable that in all the cases where special ductility is not demanded, it may not be necessary to reheat to redness castings poor in carbon after they have been hardened. The higher the temperature at which the reheating takes place, provided, however, it does not exceed a full red heat, the more is the ductility increased, while on the other hand the limit of elasticity and the ultimate tensile strength are thereby diminished, until they descend to nearly the same minima which characterize ingot iron or ingot steel of the same composition, which have been heated to redness after hardening. By modifying this reheating on the other hand, it is possible to bring the hardened castings to intermediate stages of these qualities, quite as is the case, as we have seen, with the hardened drawn iron or steel. All becomes clear and easily understood if we only consider that the figures given in Table III. (*vide* page 504 *ante*) for the hardened and reheated castings ought not to be compared with the figures in the same column for the hardened, but with those for the unhardened and drawn sorts of iron and steel. The small differences in the properties of the specimens corresponding with each other, in degrees of hardness which still remain, are by no means greater than those which occur in the case of comparisons made exclusively between drawn sorts of iron and steel, and they may easily be explained by different degrees of reheating after the hardening.

It may be stated as an objection to the correctness of the explanation of these important facts now proposed that the properties of Martin castings may be improved, as Tables IV. and V. show, merely by heating to redness without the help of proper hardening. It must be admitted that it is possible, when skill and practice have been acquired, to attain merely by heating to redness followed by slow cooling of the drawn iron or steel a diminution in the limit of elasticity and ultimate tensile strength; and as the same thing can also happen,

as Table VI. shows, with undrawn ingots, it appears very strange at the first glance that these properties can also be increased in the undrawn ingot metal merely by heating to redness. It was also just the circumstance that in the accounts of the Terrenoire process, with the exception of the addition of manganese-silicon-iron, the heating to redness was almost exclusively dwelt upon, and it was stated that merely with its help it was possible to make undrawn compact ingot metal equal to that which had been drawn that made me doubtful of the whole thing, until I had an opportunity of studying it more thoroughly at the Paris Exhibition.

An examination of Tables IV. and V., however, shows, without going further, that if the limit of elasticity and breaking strain of the castings be somewhat increased merely by heating to redness, this increase is by no means so great as that attained by hardening the same pieces. In fact, it also stands in complete correspondence with the views expressed above as to the causes of hardening that an undrawn ingot metal ought to have, its limit of elasticity and ultimate tensile strength somewhat increased merely by sufficiently strong heating, for though cooling takes place comparatively very slowly, it is, however, provided it goes on from without inwards, always attended with a compression caused by contraction; but so long as this compressing force, in consequence of the slow cooling, is weaker than that attained by common drawing, are the alteration of the texture of the material and the increase of the limit of elasticity less than when caused by drawing.

The consequence of this must be that a drawn iron or steel—above all, when the drawing, as in the case of hammering, has been continued to a low temperature—loses in limit of elasticity and ultimate tensile strength by heating to redness followed by slow cooling, while an undrawn ingot may increase to some extent in these properties, although in a smaller proportion, according as the degree of heating was less and the cooling slower. On the other hand, by sufficiently rapid cooling or actual hardening, the oft-mentioned properties are increased in the material to a higher degree than can be attained merely by drawing; but by renewed heating this excess can be again removed.

That the ductility of the undrawn ingot metal has increased by heating and slow cooling, as Tables IV. and V. show, still more than by a rapid cooling, stands in full correspondence with the common effects of heating, and therefore require no further notice; but on the other hand, it remains to endeavor to explain how it could be possible that the experiments with unannealed and annealed ingots, the results of which are given in Table VI., should show results of heating so different from those just stated, that it even produced in them a slight diminution in the limit of elasticity and ultimate tensile strength. One cannot of course give any decided utterance on this point without being himself present at the experiments, and in the absence of detailed statements of the degree of heating and the manner of cooling, but it appears to me to be probable that the cause of this difference is to be sought for in the degree of heating having been considerably lower in this case, for if it had been sufficiently low, it is not to be expected that the cooling following upon it would have been able to exercise any noteworthy influence on the limit of elasticity and ultimate tensile strength of the ingot, especially if the cooling had been very slow. A deficiency of compactness in these ingots may also possibly have conduced thereto; but that their heating was actually comparatively trifling appears to be confirmed by the consequent increase of the percentage of elongation being so small.

Another remark which also may be urged against the conception of the influence of the manner of cooling here expressed is, that if these changes be caused by the compression produced by contraction, the same ought also to take place at the first cooling of the ingot, the rather because this proceeds from a still higher temperature. But the difference is quite manifest. In the latter case we have a fused mass which, through the cooling of the walls of the mould, begins to solidify at them. No compression of the material still in a a fluid state in the interior can, however, come in question, for it is thus pressed only upwards; and when the whole mass is solidified, we have here already from

the beginning such a difference between the temperature of the outer and inner layers that the material never comes to be exposed to nearly so severe a pressure as when we with like rapidity cool a solid body, which, when the cooling begins, is apt to be warmer in the outer than in the inner layers.

Although the pressure must thus be very much less in the forming of ingots than in cooling after a renewed heating, it is, however, without question very noticeable in the former case, which is best seen both by the behavior of pig iron, which becomes whiter when rapidly cooled in metal moulds than when run out into sand or clay moulds, and by steel castings being less coarse in the grain when cast in metal moulds than when cast in others; but the contraction which takes place in the formation of ingots is at all events not sufficient to bring about in the metal such an alteration as is caused by drawing.

THE EMPLOYMENT OF THE TERRENOIRE PROCESS

Terrenoire at the time of the Paris Exhibition had not been able to get into proper order its large oil basin and crane intended for the hardening of large pieces, and the greater portion beyond comparison of the large pieces of compact Martin casting which Terrenoire exhibited were therefore not yet finished, but to be looked upon as in process of manufacture. This, on the other hand, did not hold good of the armor-piercing projectiles, which have already, for a number of years, been made on a great scale of Martin steel merely by casting in metal moulds, followed by hardening and tempering. The moulds employed for this purpose consisted of two pieces standing one above the other, of which the under formed the point of the projectile and the upper its cylindrical part, but upon the latter there was besides a half meter high contracted sunkhead in dry sand. These projectiles are cast of steel with 0.45–0.6 per cent. carbon, 0.25–0.3 per cent. silicon, and 0.5–0.6 per cent. manganese. The hollow projectiles, too, are cast massive and afterwards bored out, but besides they are subjected to no other operation than hardening, followed by tempering. The hardening proceeds by dipping the pointed part, after the whole projectile has been heated to a red heat, first into water until the redness has disappeared from its surface, after which the whole piece is sunk in an oil-bath, where it is allowed to lie until it is quite cool. Then follows a gentle heating for tempering, or only so strong that the adhering oil is removed. The oil-bath intended for the hardening, it was considered, ought to be at least so large that the weight of oil was four times greater than that of the piece that was to be hardened.

Very satisfactory experiments had indeed been made at the time of the Exhibition with some small cannon tubes made of compact Martin castings, but it was first during winter that the Terrenoire process may be said rightly to have got its baptism of fire; for according to a communication which M. Pourcel has kindly sent me quite lately, two armor plates cast of their compact Martin iron have been tested at Gavre with great success. One of these plates, both of which were 350 mm. thick, contained 0.239 per cent. carbon, 0.15 per cent. silicon, and quite a small quantity of manganese. This armor plate was hardened in oil and reheated afterwards. The other somewhat harder plate, with 0.314 per cent. carbon, was only heated to redness. These were tested with a 320 mm. cannon in quite the same way as several hammered and rolled armor plates of the same dimensions from Creusot, partly at right angles to the plates with pointed projectiles of hardened cast iron, and partly obliquely to the plates with projectiles cast at Terrenoire of compact Martin steel and hardened. In the former case the charge of powder was 53 kilogrammes, and the speed of the projectile 370.6–371.7 meters, and in the latter the charge of powder was 63 kilogrammes, and the speed of the projectile 414.8–432.2 meters per second. Neither of these two plates was penetrated by a shot, though cracks of course arose. Yet the unhammered and unrolled armor plates of Terrenoire have stood the test better than the hammered and rolled plate from Creusot. Notwithstanding the lesser content of carbon in the hardened plates, the projectiles did not penetrate so deeply into them as into those that were only heated to redness

(318 mm. against 350 mm. for the perpendicular shots, and 204 mm. against 234 mm. for the oblique), while the former, so far as can be judged from the drawings received, were at least not worse cracked than the latter.

Both many and great are the advantages which we appear to be justified in expecting from this process, for it renders it possible in many cases to replace with an oil basin and a crane the enormous steam hammers which are otherwise necessary for the production of large forgings of ingot metal, and which are so costly that only comparatively few works can procure them. Great care is indeed required, not only at the Martin furnaces themselves, in order to obtain from them materials which are at the same time compact and of the proper degree of hardness or the requisite composition, but also at the succeeding heatings; but without great care no success is in fact attained in the hammering of ingot metal in the long run, and the danger of burning must in such a case be greater, for even if the hammer be heavy enough to make its influence properly felt to the very core of the metal, which is often not the case, the forging of large pieces is done at many heats, and in such cases such parts as lie nearest to those that for the time are under the hammer may easily be burned to a greater or less extent, for they have been strongly heated without being again hammered.

THE ADVANTAGE OF THE HARDENING OF DRAWN INGOT IRON.

Besides the extensive employment which ought to be expected in the way now pointed out for the hardening of undrawn ingot metal, it appears also as if we might reckon on the hardening of hammered or rolled articles of iron being more generally used than has hitherto been the case, and yet the great increase of strength and toughness which hardening produces in pretty compact iron that has been refined in the open hearth has been known so long that even Sefström refers to it. Still more striking, as we have seen, is the increase thereby attained in the strength of the compact ingot iron, and at some works, both Swedish and foreign, it has been turned to account more particularly in the making of rings for cannon; but the use of hardening in similar cases is far from being so general as it deserves to be. It is already common at many works to subject the pieces as soon as they are finished to a uniform heating to a red heat, in order to remove the tension which unequal or partial heating and working often produce in articles of ingot iron, but only perhaps in the cases in which the content of carbon exceeds 0.3 per cent., or in which the principal stress is laid upon the attainment of the greatest possible ductility, ought the pieces afterwards to be cooled slowly. In proportion as more importance is attached to a high limit of elasticity and breaking strain, it appears on the other hand desirable that the heated finished pieces ought to be hardened.

In his valuable paper, "Remarks on the Manufacture of Steel, and the Mode of Working it," Chernoff sets forth, with very warm approval, the great advantages of always hardening articles of ingot iron, and he there points out also how it is possible merely by hardening to remove the coarse crystalline texture, and the consequent brittleness, which distinguish iron which has been long exposed to slight concussions. This alteration, as is well known, is specially prevalent in wagon axles, and it has accordingly given occasion to the precautionary measure that all wagon axles, even if they are to outward appearance never so faultless, are rejected, or at least subjected to special examination, after running a certain number of miles. The advantage of getting these axles made again serviceable merely by hardening is manifest, and the possibility of doing so appears accordingly to be deserving of thorough investigation.

[The tables referred to in this Article are for convenience all placed together on the following pages.]

TABLE I.—AVERAGES OF BREAKING TESTS OF INGOT IRON PLATES CARRIED OUT BY C. A. DELLVIK AT THE SWEDISH IRON BOARD'S TESTING INSTITUTE, ON STRIPS OF 70 BY 9 MILLIMETERS' SECTION AND 200 MILLIMETERS IN LENGTH.

AVERAGE	THE PLATES' CONTENTS OF					UNHEATED.					HEATED TO REDNESS.					HARDENED IN WATER.				
	Carbon per cent.	Silicon per cent.	Phosphorus per cent.	Sulphur per cent.	Manganese per cent.	Limit of Elasticity in Kilogrammes per Square Millimeter.	Breaking Load in Kilogrammes per Square Millimeter of the original Sectional Area.	Elongation per cent. on a Length of 200 Millimeters.	Contraction per cent. of the original Sectional Area.	Ratio of Elastic to Breaking Weight.	Limit of Elasticity in Kilogrammes per Square Millimeter.	Breaking Load in Kilogrammes per Square Millimeter of the original Sectional Area.	Elongation per cent. on a Length of 200 Millimeters.	Contraction per cent. of the original Sectional Area.	Ratio of Elastic to Breaking Weight.	Limit of Elasticity in Kilogrammes per Square Millimeter.	Breaking Load in Kilogrammes per Square Millimeter of the original Sectional Area.	Elongation per cent. on a Length of 200 Millimeters.	Contraction per cent. of the original Sectional Area.	Ratio of Elastic to Breaking Weight.
Of ten tests of plates from five different Bessemer ingots from Motala (Bangbro)....	0.1 to 0.3	0.017 to 0.029	0.028 to 0.031	trace to 0.01	0.151 to 0.267	21.5	42.6	26.9	50.1	0.506	18.4	38.2	31.6	54.7	0.482	24.3	63.5	15.7	33.3	0.383
Of ten tests of plates from five different Bessemer ingots from Iggesund.....	0.1 to 0.3	0.016 to 0.037	0.016 to 0.024	0.02 to 0.025	0.094 to 0.360	22.3	43.8	27.4	50.9	0.512	19.8	41.7	29.9	53.3	0.475	26.0	64.8	14.8	33.3	0.403
Of ten tests of plates from five different Bessemer ingots from Uddeholm.....	0.05 to 0.18	0.006 to 0.018	0.020 to 0.028	0. to trace	0.050 to 0.122	18.5	37.7	30.6	57.0	0.491	17.7	37.0	32.2	58.3	0.478	26.7	65 1	14.3	38.1	0.411
Of all the Bessemer plates.....	..	..	..	..	..	20.8	41.4	28.3	52.7	0.502	18.6	39.0	31.2	55.4	0.477	25.7	64.5	14.9	34.9	0.398
Of two tests of plates from different Martin ingots from Uddeholm.....	0.14 to 0.23	0.021 to 0.042	0.011 to 0.015	0.	0.086 to 0.101	13.1	36.0	36.7	57.4	0.364	14.3	34.8	33.0	61.2	0.411	19.4	53.4	18.0	42.7	0.363
Of two tests of plates from different Martin ingots from Motala.....	0.17 to 0.22	0.018. to 0.028	0.030 to 0.034	0. to trace	0 137 to 0.273	19.1	41.0	29.7	49.2	0.466	18.7	38.8	32.4	56.7	0.482	22.7	55.1	19.3	47.8	0.412
Of all the Martin plates.....	..	..	..	..	..	16.1	38.5	33.2	53.3	0.418	16.5	36 8	32.7	58.9	0.448	21.1	54.3	18.7	45.3	0.389

TABLE II.—TESTS OF THE TENSILE STRENGTH OF PUDDLED IRON, BOTH UNHARDENED AND HARDENED, IN DIFFERENT WAYS, OF IRON REFINED IN THE OPEN HEARTH, AND OF INGOT METAL.

Maker.	Variety of Iron and Steel.	Mode of Treatment of Test Bar.	Test Bar's Contents of		Breaking Load.	Elongation per cent.	Contraction % of original Sectional Area.	Examination carried out by.	Average.
			Carbon per cent.	Phosphorus per cent.	Kilog. per sq. mm.				
Surahammar	Puddled iron, rolled	Unheated	0.20	?	34.0	19.07*	?	S‡	fiv tests
"	" " "	Heated to redness, slowly cooled in hot small charcoal	....	..	32.9	?	63.7	"	
"	" " "	" hardened in water	....	..	48.5	6.2	33.9	"	two tests
Bowling	" " "	Strongly heated and hardened in coal tar	?	?	44.2	22.4	40.5	K§	three tests
"	" " "	" " oil	?	?	45.4	18.8	33.6	"	two tests
"	" " "	" " water	?	?	51.6	19.6	34.9	"	
	Puddled iron, piece of crank-axle, sample taken in the direction of the length of the axle	Unheated	?	?	31.2	20.6	24.3	"	
	" " " "	Hardened in water	....	..	37.5	16 6	19.0	"	
	Puddled iron, piece of an armor plate, sample taken across	Unheated	?	?	24.3	4.8	5.9	"	
	" " " "	Hardened in water	...	..	25.4	3.0	4.0	"	
Lesjöfors	Hearth-refined iron, rolled	Unheated	0.06-0.08	0.02	32.9	21.2†	70.2	S‡	two tests
"	" " "	Heated to redness, slowly cooled in hot small charcoal	....	..	31.5	24.0*	66.2	"	two tests
"	" " "	" hardened in water	....	..	44.3	8.0*	63.8	"	three tests
Halsthammar	" " "	Unheated	0.07	?	35.8	16.7†	56	"	
"	" " "	Heated to redness, slowly cooled in hot small charcoal	....	..	33.4	?	74	"	
"	" " "	" hardened in water	....	..	35.6	?	58	"	
Aryd	" " "	Unheated	0.07	0.26	42.1	7.1†	15.4	"	five tests
"	" " "	Heated to redness and hardened in water	....	..	47.1	17.5*	27.9	"	three tests
Högbo	Bessemer Iron, hammered	Unheated	0.33	0.02	50.2	6.0†	62.4	"	two tests
"	" " "	Heated to redness, slowly cooled in hot small charcoal	....	..	36.0	19.0*	72.8	"	
"	" " "	" hardened in water	....	..	56.2	13.0*	57.6	"	
"	Bessemer Steel, hammered	Unheated	0.68	0.02	71.2	3.7†	34.8	"	
"	" " "	Heated to redness and hardened in water, then heated to 250 deg. C. for half an hour	....	..	72.5	1.6*	20.5	"	two tests

"	"	"	"	Unheated	1.05	0.02	72.4	3.4†	43.9	" two tests
"	"	"	"	Heated to redness and hardened in oil	....	..	101.7	0.0*	0	"
"	"	"	"	" " water	....	..	28.9	0.0*	0	"
"	"	"	"	Unheated	1.14	0.02	89.0	2.9†	40.7	" two tests
"	"	"	"	"	1.35	0.02	74.6	2.4†	14.6	" two tests
Wikmanshyttan	Uchatius steel, rolled			"	0.69	0.01	72 8	11.3†	37.7	"
	"	"	"	Heated to redness and hardened in water, then heated to 250 deg. C. for half an hour	....	..	76.6	3.0*	44.9	"
"	"	"	"	Heated to redness and hardened in oil	....	..	96.1	2.0*	0.4	"
"	"	"	"	Unheated	0.78	0 01	83.4	10.8†	28.0	"
"	"	"	"	Heated to redness, cooled slowly in hot small charcoal	....	..	68.1	?	36.0	"
"	"	"	"	" hardened in water, then heated to 250 deg. C. for half an hour	....	..	63.2	0*	0	"
"	"	"	"	Heated to redness and hardend in oil	....	..	118.4	?	9.9	"
"	"	"	"	Unheated	1.16	0.01	98.3	4.6†	12.4	"
"	"	"	"	Heated to brownness and hardened in water, then heated to 250 deg. C. for half an hour	....	..	92.5	6.0*	23.0	"
"	"	"	"	" " " " " " "	....	..	100.6	?	13.0	"
"	"	"	"	Heated to full redness and hardened in oil	....	..	38.6	0*	0	"
"	"	"	"	Unheated	1.22	0.01	101.7	4.5†	4.8	"
"	"	"	"	Heated to redness, slowly cooled in hot small charcoal	....	..	65.5	?	45.0	"
"	"	"	"	" hardened in oil	....	..	137.0	1.1*	26.0	"
"	"	"	"	Heated to full redness, and hardened in oil	....	..	71.2	0*	0	"
"	"	"	"	Unheated	1.56	0.01	85.3	2.5†	2.0	"
Krupp, Essen	Crucible Steel, hammered			"	0.62	0.02	60.1	6.4†	54.0	"
"	"	"	"	Heated to redness and hardened in oil	....	..	108.0	?	2.5	" two tests
"	"	"	"	" " " water, then heated to 250 deg. C. for half an hour	....	..	85.9	0*	7.0	"
Jowitt, Sheff'ld	Crucible steel, "chisel steel"			Strongly heated and slowly cooled in ashes	?	?	85.6	12.9	7.0	K§
"	"	"	"	" " hardened in oil	....	..	151.4	3.5	3.3	"
"	"	"	"	" " " water	....	..	63.3	0	0	"
"	"	"	"	" " " " tempered to yellow	....	..	71.0	0	0	"
"	"	"	"	" " " " " spring blue	....	..	73.7	0	0.7	"
"	"	"	"	" " " " " fall blue	....	..	78.8	0	0.7	"
"	"	"	"	Moderately heated, and slowly cooled	....	..	83.8	9.4	7.7	"
"	"	"	"	" hardened in coal tar	....	..	117.4	6.4	6.0	"
"	"	"	"	" " oil	....	..	130.1	3.5	2.7	"
"	"	"	"	Slightly heated, and slowly cooled	....	..	88.6	16.5	10.0	"
"	"	"	"	" hardened in coal tar	....	..	99.8	13.1	8.7	"
"	"	"	"	" " oil	....	..	114.7	6.8	5.0	"

* The elongation near the place of fracture is not included in this. † The elongation calculated on a length of 5 feet. S—Styffe and K—Kirkaldy.
‡ Jernkontorets Annaler, 1866. § Results of an experimental inquiry into the tensile strength of wrought iron and steel.

TABLE III.—BREAKING TESTS OF MARTIN METAL CARRIED OUT AT TERRENOIRE ON ROUND RODS 20 MILLIMETERS IN DIAMETER AND 200 MILLIMETERS IN LENGTH.

	THE RODS' CONTENTS OF					UNHARDENED.					HARDENED IN OIL.					HARDENED IN WATER.				
	Carbon per cent.	Silicon per cent.	Phosphorus per cent.	Sulphur per cent.	Manganese per cent.	Limit of Elasticity in Kilogrammes per Square Millimeter.	Breaking Load in Kilogrammes per Square Millimeter of original Sectional Area.	Elongation on a Length of 200 Millimeters.	Contraction per cent. of original Sectional Area.	Ratio of Elastic to Breaking Weight.	Limit of Elasticity in Kilogrammes per Square Millimeter.	Breaking Load in Kilogrammes per Square Millimeter of original Sectional Area.	Elongation on a Length of 200 Millimeters.	Contraction per cent. of original Sectional Area.	Ratio of Elastic to Breaking Weight.	Limit of Elasticity in Kilogrammes per Square Millimeters.	Breaking Load in Kilogrammes per Square Millimeter of original Sectional Area.	Elongation on a Length of 200 Millimeters.	Contraction per cent. of original Sectional Area.	Ratio of Elastic to Breaking Weight.
Common Martin Metal, drawn	0.15	trace	0.035	trace	0.213	18.2	36.4	32.3	65.7	0.500	31.4	46.8	23.7	66.1	0.671	33.1	50.4	18.25	71.2	0.657
" " "	0.49	"	0.070	"	0.200	23.0	48.0	24 8	40.3	0.479	46.4	71.0	12.5	26.8	0.653	49.3	78.2	7.0	35 6	0.630
" " "	0.709	"	0.062	"	0.266	30.8	68.2	10.0	8.5	0.452	67 8	97.0	1 25	3.3	0.699	Broke in pieces in hardening.				
" " "	0.875	"	0.055	"	0.250	32.8	73.2	8.4	6.8	0.448	77.8	104 6	0.8	2.0	0.745		"	"	"	
" " "	1.050	"	0.063	"	0.255	39.5	86.0	5.2	4.5	0.459	92.6	130.8	1.0	2.0	0.708		"	"	"	
" " "	0.450	"	0.067	"	0.521	26.3	51.8	24.5	47.0	0.508	41.7	76.5	12.0	40.7	0.545					
" " "	0.467	"	0.072	"	1.060	31.2	61.1	21.4	47.3	0.511	65.0	99.0	?	?	0.657					
" " "	0.515	"	0.061	"	1.305	41.2	76.5	17.4	45.7	0.539	Broke in pieces in hardening.									
" " "	0.560	"	0.058	"	2.008	47.7	88.5	10.5	32.7	0.539	"		"		"					
" " "	0.310	"	0.247	"	0.746	33 4	55.2	23.5	47.8	0.605	41.2	71.5	13.0	45.0	0.576					
" " "	0.274	"	0.273	"	0.800	36.2	56.2	24.0	57.1	0.644	42.0	76.5	13.3	43.3	0 549					
										0.633					0.552					
" " "	0.310	"	0.398	"	0.693	37.8	59.7	25.25	53.6	0 627	44.2	80.0	?	22.9	0.559					
Martin Castings: free from blow-holes undrawn											Hardened in oil, then re-heated									
	0.287	0.233	0.076	"	0.693	20.7	45.7	8.8	2.6	0.453	28.8	49.3	21.4	36.4	0.584					
" " "	0.459	0.221	0.078	"	0.670	25.2	52.2	3.5	1.5	0.483	30.3	56.0	16.9	23.4	0.541					
" " "	0 750	0.163	0.097	"	0.672	34.7	62.3	3.1	4.9	0.557	36.3	72.3	9.4	10.9	0.502					
" " "	0.875	0.322	0.085	"	0.772	37.8	60.5	1.4	?	0.625	47.8	82.4	3.0	3.1	0.580					

TABLE IV.—TESTS OF THE TENSILE STRENGTH OF MARTIN CASTINGS FREE FROM BLOWHOLES, CARRIED OUT AT TERRENOIRE.

	The Metals' Contents of			Unworked Castings.			Castings Heated to Redness.			Hardened and Slightly Re-heated.		
	Carbon per cent.	Silicon per cent.	Manganese per cent.	Limit of Elasticity Kilos. per Sq. Mm.	Breaking Load in Kilos. per Sq. Mm. of original Area.	Ratio of Elastic to Breaking Weight.	Limit of Elasticity, Kilos. per Sq. Mm.	Breaking Load in Kilos. per Sq. Mm. of original Area.	Ratio of Elastic to Breaking Weight.	Limit of Elasticity, Kilos. per Sq. Mm.	Breaking Load in Kilos. per Sq. Mm. of original Area.	Ratio of Elastic to Breaking Weight.
Soft metal.....	0.26	0.26	0.41	17.2	47.8	0.360	19.2	46.5	0.413	31.1	55.0	0.565
"				19.3	46.8	0.412	23.5	49.2	0.477	31.3	56.5	0.554
"	0.317	0.30	0.48	18.1	56.8	0.319	20.2	54 2	0.373	35.5	67.7	0.524
Averages..	...	...	...	18.2	50.5	0.360	21.0	50.0	0.420	32.6	59.7	0.546
Moderately hard metal.	0.425	0.275	0.75	31.2	62.5	0.499	36.9	72 9	0.506	39.0	76 8	0.508
" "				33.0	57.9	0.570	34.8	74.8	0.465	36.6	75.2	0.486
" "	0.45	0.35	1.10	30.8	59.8	0.515	34.0	74.0	0.460	45.0	85.0	0.530
Averages..	...	...	...	31.7	60.1	0.527	35.2	73.9	0.476	40.2	79.0	0.509
Hard metal.....	0.55	0.405	1.05	25.3	58.0	0.436	25.3	73.0	0.347	28.8	77.2	0.374
"	0.635	0.55	0.95	23.7	56.0	0.423	29.4	73.0	0.403	42.9	111.5	0.385
"				31.9	52.2	0.611	36.5	78·5	0.465	55.0	116.0	0.474
Averages..	...	...	...	27.0	55.4	0.487	30.4	74.8	0.406	42.2	101.6	0.415

TABLE V.—TESTS OF TENSILE STRENGTH CARRIED OUT AT TERRENOIRE ON ROUND RODS 14 MILLIMETERS IN DIAMETER AND 100 MILLIMETERS IN LENGTH OF MARTIN CASTINGS FREE FROM BLOWHOLES.

	The Metals' Contents of			Unheated Castings.				Heated to Cherry-Red and Hardened in Oil.*			
	Carbon per cent.	Silicon per cent.	Manganese per cent.	Limit of Elasticity Kilos. per Sq. Mm.	Breaking Load in Kilos. per Sq. Mm. of original Area.	Contraction per cent. of original Area.	Ratio of Elasticity to Breaking Weight.	Limit of Elasticity Kilos. per Sq. Mm.	Breaking Load in Kilos. per Sq. Mm. of original Area.	Contraction per cent. of original Area.	Ratio of Elasticity to Breaking Weight.
Soft Metal.....	..	0.203	0.42	23.2	49.2	45.0	0.475	38.2	62.1	35.0	0.615
"	..	0.209	0.63	23.8	50.3	?	0.473	31.5	55.1	?	0.572
"	..	0.233	0.61	20.0	45.7	?	0.438	29.6	60.0	?	0.493
"	..	0.263	0.66	26.8	51.0	43.5	0.525	?	?	?	?
Averages	0.2	0.227	0.58	23.4	49.0	..	0.478	33.1	59.1	..	0.560
Hard Metal for projectiles....	..	..	..	33.9	70.0	?	0.484	42.0	75.2	?	0.559
" "	..	..	..	33.5	76.2	?	0.440	47.1	83.0	?	0.567
" "	..	..	..	34.0	75.5	?	0.450	46.8	84.0	?	0 493
" "	..	..	..	36.0	78 0	?	0.462	41.0	79.8	?	0.514
" "	..	..	..	36.0	79.5	?	0.453	44.0	80.0	?	0.550
" "	..	..	..	36.2	76.2	?	0.475	47.8	90 0	?	0.531
" "	..	..	..	36.5	80.0	?	0.456	46.1	88.8	?	0 519
Averages.....	0.5	0.39	0.88	35.2	76.5	..	0.460	45.0	83.0	..	0.542

* The hardening of the hard metal has probably been followed by some re-heating, although this is not stated by Mr. Holley, who first published both this and Table IV.

TABLE VI.—TEST OF THE TENSILE STRENGTH OF BESSEMER METAL FROM WESTANFORS, FAGERSTA, CARRIED OUT BY MR. KIRKALDY ON ROUND RODS, 34 TO 43 MILLIMETERS IN DIAMETER, AND 244 MILLIMETERS IN LENGTH.

Per-centage of Carbon in Metal.	UNDRAWN INGOTS.											
	UNANNEALED RODS.						ANNEALED RODS.					
	Limit of Elasticity in Kilogrammes per Square Millimeter.	Breaking Load in Kilogrammes per Square Millimeter of original Sectional Area.	Elongation per cent. on a Length of 254 Millimeters.	Contraction per cent. of the original Sectional Area.	Ratio of Elastic to Breaking Weight.	Breaking Load in Kilogrammes per Square Millimeter of the Area of Fracture.	Limit of Elasticity in Kilogrammes per Square Millimeter.	Breaking Load in Kilogrammes, per Square Millimeter of original Sectional Area.	Elongation per cent. on a Length of 254 Millimeters.	Contraction per cent. of the original Sectional Area.	Ratio of Elastic to Breaking Weight.	Breaking Load in Kilogrammes per Square Millimeter of the Area of Fracture.
0.2	15.6	37.2	11.6	11.9	0.479	42.2	14.2	37.1	18.2	27.1	0.383	50.9
0.4	19.9	38.8	3.4	4.2	0.513	40.5	18.4	37.3	4.2	5.2	0.493	39.3
0.6	27.3	46.8	1.7	2.3	0.583	46·9	26.6	45.0	2.2	2.3	0.590	46.1
0.8	33.5	47.2	1.1	1.5	0.710	47.9	27.3	44.7	1.7	2.1	0.611	45.7

HAMMERED DOWN FROM INGOTS WITH 152.4 MILLIMETERS SIDE TO 50.8 MILLIMETERS SIDE.

UNANNEALED RODS.						ANNEALED RODS.					
Limit of Elasticity in Kilogrammes per Square Millimeter.	Breaking Load in Kilogrammes per Square Millimeter of the original Sectional Area.	Elongation per cent. on a Length of 254 Millimeters.	Contraction per cent. of the original Sectional Area.	Ratio of Elastic to Breaking Weight.	Breaking Load in Kilogrammes per Square Millimeter of the Area of Fracture.	Limit of Elasticity in Kilogrammes per Square Millimeter.	Breaking Load in Kilogrammes per Square Millimeter of the original Sectional Area.	Elongation per cent. on a Length of 254 Millimeters.	Contraction per cent. of the original Sectional Area.	Ratio of Elastic to Breaking Weight.	Breaking Load in Kilogrammes per Square Millimeter of the Area of Fracture.
24.7	42.1	22.5	61.3	0.587	108.8	23.3	39.6	22.2	64.1	0.587	110.3
27.6	52.7	17.9	52.5	0.523	110.9	25.7	49.8	19.1	57.6	0.516	117.5
33.5	68.8	10.2	28.4	0.487	96.1	32.6	64.6	12.7	46.0	0 504	119.6
46.8	69.3	2.2	3.2	0.674	71.6	33.4	60.5	5.5	8.1	0.552	65.8

THE FRACTURE OF CAST IRON:

VISCOSITY AND RELEGATION IN METALS.

From "Papers of Civil and Mechanical Engineers' Society.

If (said the author) we break a piece of pig iron, and examine the fractured surface, we find that it is made up of a number of small facets. These facets have, while the surface is fresh, a very high degree of polish, and they give to the surface an appearance very much resembling that which is presented by the fractured surface of wrought iron when it breaks by cleavage. A microscopical examination of the facets, however, will show that they differ very considerably from the facets of wrought iron. In the first place, every element of the surface in a cleavage fracture of wrought iron is a plane, but the facets in the broken surface of pig iron are curved. Secondly, the facets in wrought iron show the metal itself; but in pig iron the metal is covered with a thin film of graphite. It is curious to observe that, break the pig iron where you will, it always shows this film of graphite; and in some fractures little bits of the metal may be seen hanging loosely to the surface. These bits may be removed with a penknife, or sometimes with the finger-nail; and on examination they are found to be completely surrounded with graphite. It would thus appear that the pig is built up with small particles of iron cemented together with graphite, somewhat after the manner in which a mass of masonry is built up with stones and mortar, and that the strength of the pig is not the strength of the iron, but of the graphite cement. This graphite is the uncombined carbon of cast iron. It becomes more and more combined with the iron every time the metal is re-melted. Re-melting makes the metal harder and stronger; but the strength very soon reaches a limit beyond which re-melting makes the metal weaker; and the hardness goes on increasing until all the carbon is combined, when the metal is very hard and very brittle, and is known as white iron.

The facets of pig iron vary in size according to the quality of the pig. When pig iron has been re-melted and re-cast, the fractured surface of the casting is greatly altered in general appearance. An increase of microscopic power will, however, show that the facets are still there, retaining their curved shape, although they are very much diminished in size. As well as being smaller, they look towards a greater number of directions in a casting than in pig, and give the peculiar roughness to the fractured surface of the casting. They are smaller near the sides than near the middle of a casting; and they constitute what is called the grain of cast iron, their size determining whether the metal is open and coarse grained, or close and fine grained. Besides the roughness due to the size and arrangement of the facets, the surface of fracture possesses a general form which is not dependent upon the facets. If we imagine all the little projections on this rough surface to be filed off, and the metal thus removed to be used in filling up the little depressions, we shall have a mean surface, the form of which is not constant. I had observed, whilst breaking cast-iron bars transversely, that this general form of the fractured surface was sometimes flat and at other times curved; and as neither the one form nor the other appeared to be due to any flaw or unsoundness in the bar, I felt curious to know what determined the form. To gratify this curiosity I have made observations on a number of bars; and without pretending to have discovered why fracture takes place in the way it does, I have arrived at a few results which may be interesting.

The bars upon which the observations were made were square in section, being 1 inch deep by 1 inch wide, and 3 ft. 4 inches long. Each bar was supported upon two knife-edge bearings, 3 ft. apart, and a weight was lowered steadily upon it midway between the bearings. Three lines were drawn upon each bar, one over each bearing, and one in the middle

under the load. When a bar broke the distance between the center line and the fracture was measured, and it was noted whether the form of the fracture was curved or straight; if curved, the direction of the curve was also noted. Very soon it was found that the curves were all in one direction, except when interfered with by a flaw in the bar, and as the curvature was sometimes very slight, the following method was adopted for discriminating between straight and curved fractures:—The broken bar was looked at sideways, so as to show the vertical edge of the fractured surface, which would thus appear as a line; then, if it were possible to say from a mere inspection of this line which piece of the bar contained the center line, the fracture was classed as curved, if not, it was called straight. This method was, of course, used only for those fractures which were very nearly straight; but there were a great many so much curved as not to cause the slightest hesitation. By observing and recording in this manner, it was found that a great many more bars broke out of the center than in the center; and that those which broke in or near the center showed a fracture that was straight and at right angles to the upper and under surfaces of the bar; but those which broke at a distance from the center had, in a great many instances, a curved fracture of the following shape:—Starting as a perpendicular from the under-edge of the bar, the curve would bend very slightly towards the load, and would not deviate much from the perpendicular until it reached a position a little more than half way from the under to the upper edge, when it would begin to bend more sharply, increasing its curvature as it approached the upper edge of the bar, to which it would tend to set itself parallel. The curvature was usually greatest in those fractures which were furthest from the center of the bar; and the curve was always concave towards the center and downwards. . . . Even a large number of 1 inch bars would not show so great a difference as would a number of bars 2 inches deep; for in 2 inch bars the lower end of a fracture will, in some cases, be more than 1 inch farther than the upper end from the center of the bar. A fracture which is not very uncommon in 2 inch bars is of the following shape:—Beginning at the under edge, some 4 inches or 5 inches from the middle, it will travel part of the way across nearly perpendicular to the length of the bar; it will gradually increase its curvature until it becomes very sharply curved; it will then gradually flatten its curve and travel along near the upper edge until it reaches a point 1 inch or 1½ inches near the middle of the bar, when it will suddenly turn a right angle, and come out at the top, giving a rounded corner to one piece, and to the other a long taper lip with a square end about ⅛th inch thick. A fracture of this shape bears a rough resemblance to a hyperbola, having one asymptote along the upper edge of the bar, and the other perpendicular to it. But we have no 2-inch bars in this series. The following table shows the number of 1-inch bars upon which observations have been made. The first column gives the number of bars broken; the second gives the number of bars which broke with a straight fracture; the third, the number which broke with a curved fracture; and the fourth gives the distance between the fracture and the center line, as measured along the under side of the bar:

Number of bars broken.	Fracture straight.	Fracture curved.	Distance from center.	Number of bars broken.	Fracture straight.	Fracture curved.	Distance from center.
			Inches.				Inches.
28	28	0	0	2	0	2	2⅜
35	29	6	⅛	4	0	4	2½
41	26	15	¼	2	0	2	2⅝
37	20	17	⅜	2	0	2	2¾
24	8	16	½	1	0	1	3
30	19	11	⅝	1	0	1	3⅛
35	11	24	¾	1	0	1	3¼
24	4	20	⅞	1	0	1	3⅜
22	0	22	1	1	0	1	3½
15	3	12	1⅛	3	0	3	3⅝
20	0	20	1¼	2	0	2	3¾
11	0	11	1⅜	1	0	1	3⅞
14	2	12	1½	1	0	1	4⅛
11	1	10	1⅝	1	0	1	4¼
9	0	9	1¾	1	0	1	4⅜
3	0	3	1⅞	1	0	1	4½
5	0	5	2	1	0	1	4⅞
1	0	1	2⅛	1	0	1	5
3	0	3	2¼	1	0	1	5⅛
			Total....	396	151	245	—

The form of fracture described above may be very well shown by breaking a stick of sealing wax transversely. It may also be shown by breaking a rod of glass transversely; and it may very often be seen in pieces of broken sheet glass. Take a piece of ordinary sheet glass, break it into two pieces with a transverse pressure, and then examine the fracture. It will, in many cases, be found that the surface of fracture is curved; one of the pieces will have a square corner on one side, and a rounded corner on the other, whilst the other piece will have a square corner on one side, and a very acute corner on the other side. This acute corner is sometimes drawn out to a very thin sharp edge; it is this sharp edge which makes broken glass so dangerous to handle. Closer observation will show that the square corners occur on that side which was in tension while the glass was under pressure; the rounded and the acute corners being on the compressed side. This curved form of fracture will not be observed in all cases, for it depends upon the position of the fracture with respect to the point where the pressure is applied.

Since this form is assumed by such widely different materials as cast iron, sealing wax, and glass, we may conclude that it is determined by something other than the material. What, then, determines this form of fracture?

Dynamicians tell us that when fracture takes place its direction must be along the line of least resistance, or perpendicular to the line of greatest traction, or a resultant of the two. It is very natural to suppose that these several lines would, in a square bar of uniform section, be all together at the center of the bar; but the observations show that this is not usually the case, and that fracture takes place away from the center more frequently than at the center. Even then it might be supposed that the fracture would be straight, and perpendicular to the sides of the bar, that being the shortest line, and, therefore, other things equal, the line of least resistance. But it is not so. Yet, whatever may be the position and direction of the line of fracture, it must be concluded that that line is the resultant of the line of least resistance, and the perpendicular to the line of greatest traction. Let us see whether any relation can be found between the line of fracture and the distribution of stress.

Some years ago, Sir George Airy made some researches into the distribution of stress in solid rectangular beams. He considered the stresses in a thin vertical lamina of a horizontal beam, supported at each end, and carrying merely its own weight. Such a beam would, of course, be carrying a uniformly-distributed load. By these researches he was led to the conclusion that the stresses were distributed through the beam along curvilinear paths. The curves for the two sets of stress are similar, but opposite; that is to say, the curves representing the tensile stress are concave upwards, while those representing the compressive stress are concave downwards, and the two sets of curves cross each other. These curves are shown in a diagram in "Rankine's Applied Mechanics," p. 342, Fig. 146, sixth edition, and are there called lines of principal stress. Some time ago I attempted to trace out these lines of principal stress with the aid of polarized light. To do this I used a glass bar, rectangular in section, 2 inches deep by 1 inch thick, and 1 ft. long. This was screwed into a frame, and pressure applied to it in such a manner as to imitate a distributed load. It was, while in this condition, put in the dark field of the polariscope in a known angular position, and a series of observations made and recorded. The angle was then changed and another series of observations made. This was repeated until a large number of points were obtained and laid on paper. The result showed that the two sets of curves crossed, that is to say, the curves representing tension crossed those representing compression at right angles to each other in all parts of the bar; and that there was no part of the bar without stress.

Now, then, how will these lines of principal stress help to explain the direction of the line of fracture? This way. Firstly, other things equal, the line of least resistance would be the shortest line across the bar, and would be perpendicular to the sides. The fracture would tend to follow that line. Secondly, other things equal, the line of fracture

would tend to set itself at right angles to the lines of principal tensile stress. Now any line other than the center line crossing these curves at right angles, would itself be curved, and would be concave towards the center and downwards. It would, in fact, coincide with one of the lines of principal compressive stress. The fracture, then, tending to follow both of these directions, would follow neither, but would lie somewhere between the two; it would be a resultant of the two; and this is where observation finds it, for although it is curved in such a manner as to have its concave side directed towards the center of the bar and downwards, yet it is not sufficiently bent to set itself at right angles to the lines of principal tensile stress. When the fracture occurs in the middle of the bar, the line is straight, and perpendicular to the sides, because any tendency which may exist to bend it in one direction is balanced by an equal tendency to bend it in the opposite direction. In this position it is perpendicular to all the lines of principal stress as well as to the sides of the bar. This relation which the line of fracture bears to the line of least resistance and the lines of principal stress may perhaps be made clearer by a suitable diagram, which may be drawn in the following manner:—Make a copy of Rankine's diagram to a larger scale, omitting the lines of compression, and increasing the number of the lines of tension. Now, at a position midway between the ends, draw a perpendicular to the sides of the bar; this line will be perpendicular to all the lines of principal stress, because these lines are, in this position, horizontal; it will also be a line of least resistance; and it will be a line of central fracture. Again, draw on either side of the center a line of fracture as shown on the plate, or as described above for a 2-inch bar; then, from the lowest point of the fracture, draw a perpendicular to the sides of the bar; this will be a line of least resistance; from the same point draw a line, intersecting at right angles all the lines of principal tensile stress; this line will be curved, and will be concave towards the center of the bar and downwards. When these three lines are carefully drawn the line of fracture will be found to lie between the other two.

The observation of the three materials, cast iron, sealing wax, and glass, so curiously resembling each other in their line of fracture, has led me to inquire whether they have any other resemblance.

All bodies resist distortion. The particles of bodies having taken up certain positions, resist any force which tends to make them take up other positions; there can be no relative motion among them without the absorption of force; and if the force impressed upon them be sufficiently great to partly overcome, and yet not sufficient to completely overcome, the resistance, the particles return to their first position. The property which enables them to return is elasticity. By experiments on the elasticity of solid bodies it has been found that when the bodies have been distorted they do not completely return to their original shape after the removal of the distorting force; hence it is said that solids are not perfectly elastic bodies. Now this incomplete return shows that bodies possess another property which, in this phase at least, is opposed to elasticity. It does not, however, oppose elasticity in all its phases; for in its resistance to a distorting force it helps elasticity against the force, but when the force is removed it opposes elasticity, and prevents the body from returning to its original shape. It appears, then, that one of the functions of this property, which bears the name of viscosity, is to resist motion, or to absorb motion. This is also one of the functions of elasticity, for elasticity can absorb motion, but whatever motion it absorbs it can give out again as motion. In this way elasticity may be regarded as a reflector of motion. Not so, however, with viscosity; it cannot reflect motion; for having absorbed motion it cannot give it out again in the same form. Viscosity utterly destroys motion as such. But, although the motion disappears, no force is lost, for it is given out in another form; for viscosity has the power of transforming molar motion into molecular motion, or if the terms be preferable, of converting ordinary visible motion into heat. So that if motion be put into a viscous body, its temperature becomes raised. In this respect, viscosity resembles friction. In fact, it may be regarded as a kind of intermolecular friction.

Viscosity is possessed by fluids as well as by solids, for it is found in water and other liquids, in air and other gases; and it is even supposed to exist in the ether of space, the celestial ether which has been so triumphantly pointed to by the physicist as an example of a perfect fluid—a fluid which offers no resistance to a change of shape. Modern astronomy has shown that bodies of small mass, such as comets, are retarded in their motions through space; they do not come to their perihelion at the calculated time; hence it is inferred that they are ploughing their way through a resisting medium, and that the ether is a viscous fluid. The astronomer now turns round upon the physicist, and tells him that his perfect fluid is little better than so much diluted treacle.

Viscosity as observed in solids varies greatly in its range, both in different bodies at the same temperature, and in the same body at different temperatures. In some bodies its range is very wide, while in others it is very narrow; but in the majority of solids it is so extremely minute as to elude observation. In this respect, again, it resembles elasticity; for elasticity has in some solids, such as india-rubber, a very wide range; whilst in others, such as glass, it has a narrow range. When a solid is stretched beyond its limits of elasticity it suffers a permanent set. In like manner when a solid is stretched beyond its limit of viscosity it suffers breakage. The range of viscosity in a given solid body depends upon the temperature of the body and the speed with which a distorting force is applied. Take a stick of sealing-wax and bend it slowly with the fingers. With care it may be bent through a large angle. Now bend it quickly. It breaks. Lower the temperature; you find you have lessened its range of viscosity and increased its elasticity; and you have greater difficulty in bending it. Now raise the temperature higher than at first: you have at the same time increased the range of viscosity, and nearly destroyed the elasticity; and the sealing-wax may be bent in all directions with the greatest ease. Similar experiments might be made on glass with similar results. Glass when made hot enough to become soft is a highly viscous body, but when cooled down to the ordinary temperature of the atmosphere its viscosity disappears to general observation. It is nevertheless viscous to some extent even at a low temperature, as is shown by the fact that glass will suffer a permanent set under an insistent pressure. This may be illustrated by describing an observation which I made upon glass tubing some years ago. Having several pieces of glass tube, some about the size of barometer tube, some smaller, and about two feet long, I put them away in a box for future use. The box had a narrow strip of wood across the bottom which prevented the tubes from lying evenly, so that they rested about midway upon the strip, with one end touching the bottom of the box, leaving the other end free. On taking the tubes out of the box many months afterwards, I found they were all bent. They had suffered a permanent set, and that, too, under a very small pressure; but the pressure had remained on them a long time.

Now viscosity may be found in the metals. It may be found in lead, in copper, in silver, in gold, in wrought iron, in cast iron. You may remember that a few years ago the society visited Mr. Kirkaldy's Testing Works, and that during our visit Mr. Kirkaldy broke two pieces of wrought iron for our edification. Those two pieces of iron were totally unlike each other in their manner of breaking, and in the appearance of their fractured surfaces. One piece was very much elongated and diminished in the area of its cross section before it separated; the other was very little altered in this respect. The first showed a highly fibrous fracture; the second a cleavage fracture. The first broke silently; the second broke with a loud snap. The first was so hot immediately after breaking as to be unpleasant to the touch; the second was not perceptibly altered in temperature. The behavior of the first piece showed that it had a considerable range of viscosity; in the second the range was reduced to a minimum. The overcoming of the viscosity in the first piece generated the heat, which raised the temperature of the iron. Those two pieces showed that the viscosity of wrought iron varies considerably in different samples, even at the same temperature. But it varies far more at different temperatures; for if

wrought iron be made red-hot or white-hot it is made highly viscous, and may, as is very well known, be hammered out or rolled out to any extent. This hammering or rolling, doing work upon the iron by overcoming its viscous resistance, generates heat in the metal, and keeps up its temperature. The effect of this may be observed at a rolling-mill, where a bar of iron may be seen to be visibly hotter immediately after passing through the rolls; but this accession of heat does not last long, for radiation is very rapid at this high temperature, and soon dissipates the heat. We see, then, that wrought iron is a highly viscous metal, and viscosity is one of the properties which help to give wrought iron its great value.

By the addition of a little carbon to wrought iron the metal is converted into steel, and its viscosity is very much diminished. By increasing the quantity of carbon, the metal becomes less and less viscous, until it is at length converted into cast iron, and then its viscosity almost disappears. But it is not entirely gone; for, if a bar of cast iron be made red-hot, it may, with care, be slightly bent. True, it cannot be bent very much; but the bending, however little, is sufficient to show that the metal is to some extent viscous. Small as this little viscosity is in hot cast iron, it is still less in the cold metal. It can, nevertheless, be found, for experiments on the strength of cast iron have shown that when strained, it suffers a permanent set, and this is only another way of saying that the metal is viscous; for without viscosity, there could be no permanent set.

So much, then, for viscosity; we pass now to regelation.

Regelation is a property which is very generally regarded as being peculiar to ice. It does not appear to have been observed in any other kinds of matter; or, if observed, nobody says anything about it. The regelation of ice has attracted a very large amount of attention on account of the part which it plays, and the great scale of its operations, in the motion of glaciers. A glacier moves like a river: it moves faster in the middle than at the sides; it bends round corners and other obstacles; it contracts its dimensions at narrow places, and widens out to fill its bed at wide places, in the same way as a river does, only it does not move so fast as a river. In fact, a glacier is now generally regarded as a solid river. Now to explain this remarkable behavior of a glacier two theories have been propounded: the first accounts for the motion by supposing that ice, although a solid, has a certain amount of viscosity which enables it to move like a fluid; the second, which is the more popular, denies the viscosity and brings in regelation to explain the motion. Regelation will explain a great many of the phenomena of glaciers, but will not explain all; and I think it will some day be found necessary to unite the two theories; for regelation is a great putting-together property, and viscosity, in virtue of the resistance with which it offers to change of shape, is a great holding-together property, and the phenomena seem to need the assistance of both. Let us observe a few of the results of regelation, and then consider what are the conditions necessary to its operation.

A boy takes a handful of newly-fallen snow, and presses it into a snow-ball; but he finds that after the snow has lain on the ground all the night and has been frozen, his snowballing propensity has received a check; for he can no longer make the particles of snow cohere. A physicist will take some snow or pounded ice, and with his Brama press will squeeze it into a solid block of transparent ice; or he will take two blocks of ice, and pressing them together with his hands, make them unite to form a single block. One of the prettiest experiments which has come under my notice is to lay a bar of ice horizontally upon two bearings at its ends, then place a thin wire upon the middle of the bar, and hang a weight to it. The wire will in time cut its way through the bar, and come out at the under side without leaving a trace of its path. These are some of the phenomena of regelation; how are they to be explained? or what are the conditions necessary to be present in order that regelation may ensue?

Some years ago Professor James Thomson showed, as a result of some researches into the laws of heat, that if certain (now well-established) laws of thermodynamics were true, then water under pressure would have its freezing

point lowered in the scale of temperature. Sir William Thomson put this to the test of experiment, and found that the freezing point of water was lowered one-seventieth of a degree on Fahrenheit's scale for every additional atmosphere of pressure; proving that his brother's deduction was right. Some physicists, using this discovery to explain regelation, say that if a quantity of snow or pounded ice be pressed together, its freezing point will be lowered, and some of the ice melted; then when the pressure is removed the freezing point will return to its normal position, and the water be frozen. The wire passing through the bar of ice is explained on this theory by supposing that the pressure of the wire upon the ice lowers the freezing point of the small portion upon which it presses; the resulting drop of water then passes round from the under side to the upper side of the wire, where, being free from pressure, it freezes again; and as this is continuous, the wire leaves no trace of its passage through the bar. Other physicists say that since it requires such an enormous pressure to lower the freezing point of water in any perceptible quantity, the pressures usually applied are not sufficient to account for regelation. They seem to disregard the fact that a great many of the forces which are combined to work under the laws of nature are individually so small as not only to elude ordinary observation, but to baffle the best observers, even when using the most refined methods which science can devise. It is a mistake not to bear this in mind; and it should not be forgotten that many of the great operations of nature are performed by the addition of a number of very small forces, and that some of the grandest results are brought about by the indefinite accumulation of infinitesimal quantities.

Now it appears to me that regelation is a quantity with two factors, either of which may vary inversely as the other. One factor has already been described; the other, which does not appear in the books, perhaps because authors think it so obvious as not to need any special mention, is the following: According to the laws of thermodynamics, motion is convertible into heat in equatible quantities. If a dynamical pressure be applied to a resisting body so as to overcome the resistance and change the shape or volume of the body, or both the shape and the volume, heat is generated in the body. In the experiments which physicists perform upon snow and pounded ice with the Bramah press a considerable amount of pressure is applied; and since the shape of the ice is very much altered, as well as its particles being squeezed closer together, heat is generated in the ice. The motion of the ram is arrested by the ice, and transformed into heat. This heat must either raise the temperature of the ice or melt some of it, according to the temperature at the beginning of the experiment, whether it be below or at the melting point. In the formation of snowballs, and the pressing of two pieces of ice together with the hands, the snow and ice are very near the melting point; but when the boy fails in his attempts at making snowballs he fails because the snow is too cold, and he cannot apply enough pressure to raise its temperature to the melting point. Put the snow into a mould, and apply sufficient pressure to raise its temperature to the proper height, then it will bind together. You see, then, that in order to effect regelation, the temperature must be brought near the melting point; and this may be done in two ways at one operation, namely, by applying sufficient pressure to lower the melting point and to raise the temperature, when, if the operation be carried far enough, some of the ice will be melted; then remove the pressure, and the water will be frozen again, because its freezing point is raised, and any surplus heat is radiated away from it. The amount of pressure needed, according to this view, depends upon the temperature of the ice at the beginning of the operation. It appears, therefore, that the temperature at which regelation may take place can vary within very narrow limits. The temperature within these limits may be called the "temperature of regelation," or the "regelative temperature," whichever is the most convenient, as it will be wanted further on.

But why make regelation the peculiar property of ice, to the exclusion of all other kinds of matter? Why not examine other kinds of matter to see if they exhibit any similar property when placed

under like conditions? For a long time after it was understood that ice floats upon water because it expands at the instant of solidification, it was taken for granted that water stood alone in this respect, and that nothing like it was to be found in the whole region of matter. It is now known that other kinds of matter behave like water when passing from the liquid to the solid form; and among them may be mentioned some of the metals, as for instance, brass, cast iron, lead, and some of its alloys. Now it appears that this phenomenon of a solid floating upon its own liquid, with which we are all familiar in the sea of ice floating upon water, this increase of volume at the instant of solidification is intimately connected with regelation; and if the two phenomena are connected we ought to find regelation in some of the metals. Let us see what can be found. We need not make any delicate experiments in the laboratory, for we may observe the phenomena as exhibited on a larger scale in the operations of the workshop. We may begin with lead, and note how it is treated in the manufacture of lead piping.

The lead pipes which are used in our houses for conveying water, and for other purposes, are made in the following manner: A strong iron cylinder is fixed with its axis in a vertical position. A ram works in it underneath, and there is a hole in the upper end of the cylinder for receiving a die. The die is made of such a size as to give the required diameter to the lead pipe. The ram is lowered and the cylinder is filled with melted lead. The lead radiates its heat through the cylinder, but in order that it may not cool down below a certain temperature, a fire is kept burning around and in contact with the cylinder. When the lead is cooled down to a little below its point of solidification, and is "set," as it is technically called, pressure is applied to the ram, and the lead is forced through the die. If the pressure be applied before the lead is sufficiently cooled, or before it is "set," a jet of liquid metal is thrown up, and a splash of lead is left on the ceiling above the cylinder, as evidence that that part of the operation was begun too soon. If the die were simply a round hole, a solid rod of lead instead of a pipe would be pushed through it, so the die is made of annular form by the insertion of a steel core in the center of the hole. But this core has to be held in position. This is done by a bar across both the core and the die inside the cylinder, so that the core cannot be forced out through the die. The lead in its passage from the cylinder has to move round this bar; for the bar acts somewhat like an island in the middle of a river; or like an island in the middle of a glacier; it cuts the stream into two halves. How are these two streams of lead to join each other so as to make a pipe? We have seen that if the lead be liquid, a jet is thrown up, and instead of forming a pipe, falls as an unpleasant shower upon the workmen. If the lead were solid, its ductility would enable it to be forced through the die in the form of two half-cylinders; but ductility would not join the two halves together. How, then, is the joining effected? I see no way of doing it except by regelation; and that regelation does really take. place appears clear when we examine the conditions of the operation. The conditions are: the lead must be "set," that is, it must be solid; and it must be kept as hot as it can be without melting. What is this but keeping it near the regelative temperature? Further, pressure must be applied to force it through the die. It appears, then, that the lead is forced against the die with a pressure which slightly lowers its melting point; and, as the pressure overcomes a viscous resistance, heat is generated in the lead, thus slightly raising its already high temperature; these two causes acting together, melt a portion of the lead. Then, before the lead gets quite through the die, the resistance diminishes; therefore the pressure diminishes; and as the pressure diminishes the melting point returns to its normal height; meanwhile, that portion of the lead which is escaping the pressure is coming nearer to the external air; its temperature is therefore being lowered, because its heat is radiated more rapidly; these two causes acting together solidify the lead—that is, regele the lead, and complete the formation of the pipe. In this way a lead pipe is formed by regelation. Regelation, then, is a property which the lead-pipe maker turns to his advantage; and in order that he may do so he recognizes the im-

portance of working with his metal at a proper temperature.

Now, is this property to be found in any other metal? I think it is; but its phenomena are too common to attract attention; for how is the welding of wrought iron accomplished if not by regelation? Welding is so well known that a description of it here would be needless; and you can easily see for yourselves how much it resembles regelation.

Having traced out regelation, as exhibited in lead, and noticed its existence in wrought iron, can we find it in cast iron? It is well known that cast iron cannot be welded, nor worked in any way at the forge; but I had noticed, among the many phenomena displayed in the foundry, two or three points which led me to think that a trace of regelation might, if properly sought, be found in cast iron. With this in view I made some experiments upon cast iron at a high temperature. In these experiments I was very ably joined by the foreman of the moulders, who, after receiving my explanation of what I wanted to find, took a warm interest in it, and gave me some very useful assistance; but notwithstanding all our care in bringing about the requisite conditions, and in excluding, as far as possible, the disturbing influences, our attempts failed to disclose anything that could be called regelation. Reflecting upon these experiments, I began to consider what are the conditions necessary to the successful welding of wrought iron. The conditions are, a proper temperature, a clean fire and pressure. Now, the clean fire gave a clue to the discovery of the secret. It is known to every smith that certain matters getting into his fire will spoil it for welding; among these are sulphur, lead, brass, and to a less extent, cast iron. What is there in cast iron that can spoil the fire for welding? It cannot be the carbon, because carbon is one of the most important elements used in making a fire. What, then, is it? Let us trace out the phenomena. With a clean fire a smith finds no difficulty in welding good wrought iron; but he finds a little difficulty in welding spring steel, that is, iron containing a little carbon; with a little higher quality of steel he finds a little greater difficulty; and as the steel gets more steely, that is, as the iron contains a larger and larger percentage of carbon, so the difficulty of welding increases; until, when the iron contains as much carbon as it can take up, and thereby becomes cast iron, it cannot be welded at all. The evidence points strongly towards the carbon as being the disturbing agent; and yet the carbon which is burnt in the fire exercises no disturbing influence. But the carbon in cast iron is not in the same form as the carbon in the fire: in the fire it takes the ordinary combustible form; in cast iron it takes the form known as graphite. This difference of form might make all the difference in its influence upon welding. Smiths sometimes dip the iron which they are heating into sand, to prevent the projecting corners from burning away before the iron is hot enough throughout the surfaces which they intend to weld together; and the sand does not prevent the welding. Remembering this, I thought if two pieces of wrought iron were similarly dipped into some powdered graphite, it would serve as a test of the influence of graphite upon welding, and therefore upon the regelation of iron. Acting upon this thought, I induced a smith to make an experiment, under my observation, in the following manner: he took two pieces of wrought iron and welded them together, in order to show that his fire was clean, or to show that there was nothing in his fire which could spoil the welding; he then cut the bar into two pieces a few inches beyond the weld, and heated them again; this time he dipped the two hot ends into the powdered graphite, and then tried to weld them together, but failed; for the two pieces of iron would not unite. You see we had throughout the experiment the same fire, the same iron, the same everything, except the graphite; when the graphite was *not* used the welding was successful; but when the graphite *was* used the welding failed. So it turns out, after all, that carbon is the disturbing element which prevents the regelation of cast iron; and in order that it may exert its influence it must be in the form of graphite, that form in which it is found in cast iron.

PRACTICAL RULES FOR THE USE OF TELEODYNAMIC CABLES.

By M. LEAUTE.

Translated from "Revue Industrielle" for VAN NOSTRAND'S MAGAZINE.

IN order to insure a satisfactory transmission of power by cables, it is not sufficient that the rope should be merely capable of resisting the tensions to which this use subjects it, but it is also necessary that it should insure uniformity of action. In other words, it is necessary to take into account at the same time, the conditions of resistance of the cable and those which relate to regularity of motion. This is not at present done; for in the formulas now in use regularity of movement is not taken into account.

It is then necessary to reconsider this problem, and to take into account both of these conditions, and since the regularity is intimately related to the deflection $\frac{f}{2l}$ (f being the deflection of one of the strands of the cable, and l the half span between supports) the first thing to be done is to determine the value to be admitted for each case of this quantity.

The deflection which may be as much as $\frac{1}{15}$ or $\frac{1}{20}$ for small distances of 20 or 30 meters ought not in some cases to be more than $\frac{1}{40}$.

From a number of experiments made by M. Berard at Pont de Buis, it appears that with weak cables, the accidental variations of length, due to changes in temperature and humidity, give rise to so great variations in deflection as to subject the machinery driven to some danger.

We will add that these variations in deflection modify at the same time the coefficient of regularity, and change thereby the conditions of transmitting the power.

Whatever it be, the relative deflection should be fixed in the first place. If we designate it by m, and the deflections of the conducting and returning ropes respectively F and f; also by k the ratio between them (which should be at most equal to 2 to avoid slipping), we have

$$f=k\mathrm{F}$$

and

$$f^2+\mathrm{F}^2=8m^2l^2$$

by reason of the inextensibility of the cable.

We deduce from this

$$\mathrm{F}=2ml\sqrt{\frac{2}{1+k^2}} \qquad f=2mlk\sqrt{\frac{2}{1+k^2}}$$

The tensions of the two branches are furnished by the equations

$$a\mathrm{T}=\frac{pl^2}{2\mathrm{F}}=\frac{pl}{4m}\sqrt{\frac{1+k^2}{2}}$$

$$at=\frac{pl^2}{2f}=\frac{pl}{4m}\,\frac{1}{k}\sqrt{\frac{1+k^2}{2}}$$

where p is the weight of the cable per meter, and a the mass of a unit of length.

If now we let N represent the number of horse-powers transmitted, and V the velocity of the cable

$$\frac{75\mathrm{N}}{\mathrm{V}}=a(\mathrm{T}-t)=\frac{pl}{4m}\sqrt{\frac{1+k^2}{2}}\left(1-\frac{1}{k}\right)$$

from which we deduce for the value of p in kilogrammes, V and l being in meters

$$p=\frac{300m\mathrm{N}}{\mathrm{V}l\left(1-\frac{1}{k}\right)\sqrt{\frac{1+k^2}{2}}}$$

The area of the section in millimeters, if the material is iron with a density of $\frac{1000}{114}$ would be

$$\mathrm{S}=114p=\frac{34{,}200\,m\,\mathrm{N}}{\mathrm{V}l}\,\frac{k}{k-1}\sqrt{\frac{2}{1+k^2}}$$

We can deduce from this the tension proportioned to the square millimeter in the conducting rope. We have then

$$\mathrm{U}=\frac{a(\mathrm{T}+\mathrm{V}^2)}{\mathrm{S}}=\frac{l}{456m}\sqrt{\frac{1+k^2}{2}}+\frac{\mathrm{V}^2}{114g}$$

As for the tension in the cable occasioned by the passage over the pulleys, it is known to be

$$u=\frac{20{,}000\,d}{\mathrm{D}};$$

d being the diameter of wires forming the cable and D being the diameter of the pulley, both in millimeters.

If we assume 15 kilogrammes as a maximum strain per square millimeter, we have the equation

$$\frac{20{,}000\,d}{D} = 15 - U$$

which affords the value of d on terms of D.

The diameter of the wire being obtained, we may find their number by the equation

$$i = \frac{4S}{\pi d^2} = 145\,\frac{p}{d^2}$$

which completes the determination of the cable to be employed.

MEANS ADOPTED FOR RANGING THE CENTER LINE OF THE ST. GOTHARD TUNNEL.

By C. DOLEZALEK, Section-Engineer of the St. Gothard Railway.

From Abstracts published by Institution of Civil Engineers.

THE axis of the St. Gothard tunnel is a straight line about 9¼ miles long, with rising gradients of 1 in 172 and 1 in 1,000 respectively from both ends towards its center. At its extremities, viz: in Göschenen and Airolo, observatories were erected, distant 585 and 358 meters respectively from the tunnel portals, in which were set up the transit instruments previously used in laying out the Mont Cenis tunnel.

The direction of the center line is given from the observatory at night by a lamp placed over that point in it, inside the tunnel, which can be accurately observed directly, its ranging being thence produced by a theodolite as far as the heading permits. A direct observation as far into the tunnel as possible is therefore of the greatest importance, and to obtain this as well as longer station lengths for the ranging in the interior of the tunnel, the Author devised the contrivances which form the subject of this paper.

In 1875, to allow the signal to be shown at the right moment to the observer, telegraphic communication was established between the portal and the observatory, in both of which batteries with Morse's instruments were set up, while, in the unfinished tunnel itself, a wire was joined on by the use of portable field telegraphs.

As petroleum lamps with a bright flame proved far superior to common miners' lamps for signaling at long distances, the Author constructed with the brilliant-burner ("Rundbrenner") of Schuster & Baer of Berlin, which gave on trial 1.8 time better illumination than the ordinary petroleum lamp. This burner has a double set of pinions moving two half wicks with the greatest regularity, and is screwed on to a large metal vessel having what is called a "double-vase ring." As this allows petroleum to be afterwards poured in without unscrewing the wick-holder, the centering of the lamp (over any station) is not thrown out during the whole period of its use, since the openings in the two rings can be made to coincide or not, at will. The vessel is now leveled on a movable bronze tripod, their centers being made accurately to coincide. This concentric position is in the first instance secured by the maker, but if thrown out at any time, the ring, on which the lamp rests, can be so set by small screws, moving in a circular slit, that the middle of the wick shall be concentric with the tripod, the ring in this case being eccentric to it. This adjustment, however, ought not to be necessary if the lamp is carefully handled. A cylindrical metal mirror is provided to intensify the brilliancy of the flame. This signal lamp surpassed all others in giving far longer station lengths under similar conditions; but it may even yet be advisable to devise apparatus for using the electric light in its place.

To diminish still more the delays and inaccuracies incident on such frequent settings-up of instrument and signal in the tunnel, the Author further constructed a stand applicable to either. It

is in two parts, a top plate of metal resting on a larger circular one of wood to which three legs are attached. This top plate is separate from the lower one, though capable of being centered accurately with it under or over any required point inside the tunnel, such point being denoted by a notch on an iron cramp, which is driven into the ground. The weight (nearly 31 lbs.) of the metal plate ensures its steadiness, as its three pointed foot-screws work in small cups let into the wooden plate; by these it is leveled, and when the lamp is placed on it for use, it can be turned round and clamped in any direction.

Every station in the center line was fixed by the mean of eight distinct settings-up of the lamp, by which all level and collimation errors were eliminated from the observations. To deduce this mean readily, the metal plate consists of a bronze plate sliding in a cast-iron frame and provided with a clamp and tangent screw. The center of the bronze plate is given by a notch on either side, while to the two edges of the cast-iron frame strips of gummed paper are affixed, on which each observation is to be recorded by a pencil mark. To the mean of these marks the center of the bronze plate is now set by the notch, and in order that it may necessarily be coincident with that of either lamp or theodolite, as each is successively set up upon the plate, three small grooves radiate from it at angles of 120°, in which are secured the feet of either instrument of whatever size. At the next station the used paper-strips are scraped off, and fresh ones affixed. A plummet and line are attached to the stand for centering purposes.

The advantages claimed for this stand lie in the remarkable speed of "setting-up," in the elimination of all possible errors in the operation, and in the ready insertion of the lamp upon it on the center line; it is also easily carried about the tunnel packed in a chest. The wooden portion is only 1 meter high besides the round wooded plate of 0.5 meter outer, and 0.34 meter inner, diameter. Lead weights are attached to the lower parts of the legs to keep them steady if accidentally pushed. Weights above 20 kilogrammes (44 lbs.) should be made up from smaller ones to facilitate their manipulation; and since all the material, instruments, &c., are always forwarded from point to point in the tunnel on trollies, the transport of these lead weights offers no difficulty.

A light transit without vertical and horizontal circles, but with a powerful telescope magnifying thirty times, is advocated for ranging purposes inside the tunnel, and by its use great rapidity in the work is anticipated.

REPORTS OF ENGINEERING SOCIETIES.

BOSTON SOCIETY OF CIVIL ENGINEERS.—The latest published transactions that have reached us are:

"Production and Transmission of Power by Electricity," by Geo. W. Blodgett.

"Rock Blasting and Machine Drilling," by William Whittaker.

ENGINEERS' CLUB OF PHILADELPHIA.—Record of Meeting April 17th.

Mr. Frederic Graff, C. E., President, in the chair.

Mr. Coleman Sellers, Jr., M. E., read a paper on the history of the construction of the Mexico and Vera Cruz Railroad, illustrating his remarks with numerous photographs and maps obtained during a recent trip to the country of the Montezumas. As early as 1837 the project was broached, and from that time until it was finally opened in 1873, by President Lerdo, the road suffered an alternation of successes and defeats. During its progress forty different Presidents and one Emperor governed our unfortunate neighbor, and each government had, in turn, to be won over to the plans of the friends of this enterprise, and that in spite of a powerful opposition from various classes of the community. Not only were these difficulties surmounted, but those offered by the climate and the natural obstacles of the route were likewise overcome. At length, after years of labor, and the expenditure of millions of money, the road is now an established success; and is to-day one of the grandest specimens of engineering the world can show. The road is 260 miles long; is laid with steel rails; is thoroughly equipped with engines and rolling stock; has fine iron bridges, substantial stone stations and all tunnels, masonry, &c., and of the best character. The grades and curves are numerous and excessive. The highest point of the road is 8,200 feet above the sea. It ascends 6,500 feet in sixty miles, and in one case climbs 2,000 feet in fifteen miles.

Mr. Chas. G. Darrach, C. E., read an extract from a law recently passed by the State of Wisconsin, making it a crime to allow any sewage or unhealthful matter to be deposited in the rivers running through the City of Milwaukee, entitled, "An Act to preserve and promote the public health in the City of Milwaukee." He called attention to the interest now being taken by the City of Chicago upon the same

subject, and read an extract from a recent work on sewerage by Julius W. Adams, C. E.

The regular business meeting of the Engineers' Club of Philadelphia was held on Saturday evening, May 1st. The following was presented by Mr. C. E. Billin, C. E.:

"The present condition of the profession of land surveyor in our State, the want of accurate knowledge in regard to county and other boundaries, and the very erroneous county and state maps current, are a disgrace to Pennsylvania and to its engineers. The club cannot possibly undertake any more needed work of reform and improvement. The attempt to improve upon present methods and results in any engineering work, however humble, should call forth hearty approval and earnest work from the club. In furtherance of the remarks and suggestions which I made at the meeting of the Club, held March 20th, I would respectfully move:

"'That a commmittee of five members be appointed by the Chair, who shall take into consideration the subject of the improvement of the present methods of land surveying, the better location of county and other boundaries, and the collection of information in regard to the geography and topography of the several portions of the State.'

"'That they shall be empowered to take such action as may appear to them as will lead to the best results in the promotion of the end in view; provided that they incur no expense to the club, except under special appropriations.'"

The following was presented by Mr. Chas. G. Darrach, C. E.:

"Resolved, That the President be requested to appoint a Committee of five, one of whom to be the Chief Engineer and Surveyor of the City, to study and suggest a plan of improved sewerage for the City of Philadelphia, and the protection of the rivers from pollution." The resolutions were passed, and Mr. Frederic Graff, C. E., President of the Club, will announce the above Committees at the next meeting.

Prof. L. M. Haupt, C. E., read a paper in favor of Rapid Transit in Philadelphia, showing the desirability of the improvement, and that the objections thereto were of the same character as those usually urged against progress.

IRON AND STEEL NOTES.

MANUFACTURE OF STEEL.—An improved process for manufacturing a high quality of steel or ingot iron, by a combination of the Bessemer and open hearth process, from pig containing much phosphorus, or phosphorus and sulphur, has been patented by Mr. E. P. Martin, of Blaenavon. He blows the molten pig in either a vertical or tipping Bessemer or other converter, with an ordinary silicious lining till nearly all the silicon is removed. He prefers to stop the blow two or three minutes before the drop of the flame. He then runs the metal (without the slag) either directly through a runner, or by the intervention of a lade, into a Siemens, Pernot or other open hearth furnace (preferably a Pernot or other rotating gas furnace). This open hearth furnace must be lined with basic material (preferably Thomas's magnesian lime bricks), and have spread on its hearth a large quantity of limestone or of lime, which he always prefers to mix with a large quantity (preferably an equal weight) of oxide of iron, so as to produce a highly basic calcareous slag, which may advantageously contain over 40 per cent. of lime and magnesia. By the action of these bases the phosphorus and a considerable amount of the sulphur are rapidly removed. The greater the agitation the more rapid will be the dephosphorization. When the charge has been brought to the desired pitch, as indicated by the fracture of a sample showing the phosphorus to be removed, the slag is tapped off before the spiegel or ferro-manganese is introduced. A part of the charge in the open hearth furnace may consist of scrap iron. A very high quality of steel may be thus produced from the cheapest materials. Mr. Martin claims not the mere dephosphorizing by basic additions, but the improved combined process described for the manufacture of steel from phosphoric pig-iron. —*Iron and Steel.*

IRON AND STEEL AT LOW TEMPERATURES.—At the meeting on Tuesday, the 10th of February, of the Institution of Civil Engineers, Mr. W. H. Barlow, F. R. S., President in the chair, a paper was read on "Iron and Steel at low temperatures," by Mr. John James Webster, Assoc. M. Inst. C.E.

The first part of the paper treated of the generally received opinion as to the condition of iron and steel at low temperatures, reference being made to the evidence given before the Royal Commission appointed to inquire into the application of iron to railway structures, and to papers read before the British Association and elsewhere. An account followed of the results of experiments by the late Sir W. Fairbairn; after which, the elaborate series by M. Knut Styffe were mentioned, and the conclusions he arrived at were stated *in extenso*. From the results of these tests as to tensile strains, it appears that the absolute strength of iron or steel was not influenced by severe cold, but that the ductility of these materials was increased. Mr. C. P. Sandberg had submitted rails of iron and of steel to a force of impact, and his deductions were quoted.

The author then gave an account of the experiments he had made on bars of wrought iron, cast iron, malleable cast iron, Bessemer steel, and best cast tool steel, with a description of the apparatus used, and of the method of conducting the experiments. The bars were tested with tensile and transverse strains, and also by impact; one-half of them at a temperature of 50 deg. Fahr., and the other half at 5 deg. Fahr. The lower temperature was obtained by placing the bars in a freezing mixture, care being taken to keep the bars covered with it during the whole time of the experiments. The results were given in eight tables, and the averages of all in a ninth table.

Three sheets of diagrams accompanied the paper; the first sheet illustrated the testing apparatus; the second and third sheets showed the extensions of the bars at the different portions of their length, the appearance of the fracture, and the percentage of elongation and of reduction of area. The results of the experiments were summarised as follows:

1. When bars of wrought iron or steel were submitted to a tensile strain and broken, their strength was not affected by severe cold (5 deg. Fahr.), but their ductility was increased about 1 per cent. in iron and 3 per cent. in steel.

2. When bars of cast iron were submitted to a transverse strain at a low temperature, their strength was diminished about 3 per cent. and their flexibility about 16 per cent.

3. When bars of wrought iron, malleable cast iron, steel, and ordinary cast iron, were subjected to impact at a temperature of 5 deg. Fahr., the force required to break them, and the extent of their flexibility, were reduced as follows, viz.:

	Reduction of Force of Impact. per cent.	Reduction of Flexibility. per cent.
Wrought iron, about	3	18
Steel (best cast tool), "	3½	17
Malleable cast iron "	4½	15
Cast iron "	21	not taken

The paper closed with a review of the experiments described, with some remarks on the conclusions arrived at, and with a statement of the opinions formed by different authorities.

A case of samples of the fractured ends of the bars used in the experiments was exhibited.

BESSEMER STEEL.—Before the adoption of the Bessemer process in the production of steel the entire production of cast steel in Great Britain was only about 50,000 tons annually, and its average price, which ranged from £50 to £60 per ton, was prohibitory of its use for many of the purposes to which it is now universally applied. In the year 1877, notwithstanding the depression of trade, the Bessemer steel produced in Great Britain alone amounted to 750,600 tons, or fifteen times the total of the former method of manufacture; while the selling price averaged only £10 per ton, and the coal consumed in producing it was less by 3,500,000 tons than would have been required in order to make the same quantity of steel by the old or Sheffield process. The total reduction of cost is equal to about £30,000,000 sterling upon the quantity manufactured in England during the year; and in this way steel has been rendered available for a vast number of purposes in which its qualities are of the greatest possible value, but from which its high price formerly excluded it. During the same year the Bessemer steel manufactured in the five other countries in which the business is chiefly conducted—namely, the United States, Belgium, Germany, France, and Sweden—raised the total output to 1,874,278 tons, with a net selling value of about £20,000,000 sterling. The works in which these operations are carried on were eighty-four in number, and represent a capital of more than three millions. According to the calculations of Mr. Price Williams, who has made the endurance of rails a matter of careful study, the substitution of Bessemer steel for iron for this purpose alone will produce a saving of expenditure during the life of one set of steel rails on all the existing lines in Great Britain of a sum of more than one hundred and seventy millions sterling. It may safely be said that there is no other instance in history of an analogous impetus to manufacture, or of an analogous economy, being the result of the brain-work of a single individual; still less is there an instance of such results being realized while the inventor was living to enjoy the fruits of his labors, and able to work in fresh directions to increase the benefits which he had already conferred upon his country and upon mankind.—*Times.*

RAILWAY NOTES.

ASIATIC RAILWAYS.—Sir Richard Temple is still supervising all the arrangements along the Bolan route. He left Quetta on the the 9th for Candahar. Active steps for railway extension are being taken in the Khyber line also, and Mr. Molesworth, Government Consulting Engineer for State Railways, has been ordered to examine the country from Peshawur to Jellalabad. The Sukkur-Dadur Railway is now completed as far as Jocobabad and is being rapidly pushed on towards Quetta. It is stated that the broad gauge will extend only to this end of the Bolan Pass, the line being continued thence on meter gauge. It seems, however, hardly possible that the Government will sanction the break of the gauge on a line of such strategical importance. The permanent way and engines, it is believed, have been already ordered in England, and at the present rate of progress, of over a mile daily, the railway should be open to Quetta before many months. There is little doubt but that it will be eventually extended to Candahar. The *Daily News'* correspondent at St. Petersburg sends some details from the *New Times* as to the proposed railway from Orenburg to Tashkend. This purely strategical line will be 1,650 miles in length, and will cost, according to the Russian journal, about £11,500 a mile, at the present value of the rouble. Here we have a proposed expenditure of nearly £20,000,000, at what must be considered a very low estimate even for a single-track railroad in such a barren rugged country. That it can pay interest on its cost within any reasonable period is impossible; but this is to be remedied by the guarantee of 5 per cent. interest by a Russian railroad bank.

ENDLESS RAILS.—The idea of making a train lay down and take up its own rails as it moves along is not a new one, but an interesting realization of it is now to be witnessed (we learn from *La Nature*) in the Jardin des Tuileries, Paris. The system is that of Clement

Ader. The rails on either side of the carriages consist of a series of joined pieces of rail with flat supporting pieces ; they enclose the system of wheels, passing down over the front and up over the end wheels, and all the wheels have two flanges to prevent any derailment. In front the chains of rail are guided by two distributing wheels, which are governed by the traction, so that, on pulling obliquely, right or left, the endless way automically follows the same direction. At the end of the train, again, are two taking-up wheels, provided with a differential motion to meet the difficulty of going in curves, which involves an extending of the rail on one side and contraction of that on the other, so that, whatever the curve (to six or seven meters' radius), the way is regularly put down and lifted. From the mechanical point of view, one is struck with the smallness of the force required to move a train thus arranged. In the Jardin des Tuileries the train consists of three carriages, capable of containing in all 30 children, and often full. These are drawn by two goats, which work thus for seven hours. The total load is about 1,000 kilogrammes. To draw a like weight in three carriages on ordinary roads would require a dozen goats, four for each vehicle (this is the number harnessed to the small carriages for children in the Champs Elysées). The economy of carriage, then, is incontestable. The normal speed is four to six kilometres per hour. The system is, of course, not designed for passenger traffic, but for goods, and in many places with bad roads or none might be very serviceable.

The Railroad Outlook.—*The Iron Age*, in an elaborate and careful examination of the prospect for railway building in the United States in 1880, reaches the conclusion that indications point to the construction of about 7,000 miles of new road, rather more than fewer, and that the demand during the year for new rails, to be used for new roads and old tracks, will reach 1,500,000 gross tons, of which the American mills can supply, under favorable circumstances, not more than 1,400,000 tons, leaving 100,000 tons to be imported.

South Australian Railways.—South Australia has now 533¼ miles of railway in working, and 475¼ miles either in course of coustruction or authorized. Alterations and additions are being effected at the Adelaide station-yard, with a view to accommodate the traffic, which will be increased as soon as the Holdfast Bay Railway, now in course of construction by a private company, is connected with the Government lines. An additional line of rails has been authorized to be laid between Adelaide and Port Adelaide. The requisite permanent way material is expected to arrive shortly, and the culverts and earthworks are in hand. Designs have been submitted for a new passenger station at Port Adelaide in which the present building will be utilized so far as is practicable. One mile of the railway has been relaid with 61 lbs. steel rails. At the Adelaide station which has been almost entirely rebuilt during the year, an hydraulic lift has been erected. An arrival platform, with additional luggage-room and engine traverser, to meet the extra traffic caused by the Holdfast Bay and Nairne lines, are fast approaching completion.—*Engineering.*

Endless-Chain Mine Railway at Fillols.*—The iron mines at Fillols, in the Canigou region, Eastern Pyrenees, are situated at a high elevation, from which the minerals are conveyed by gravitation, in small wagons on a double line of railway, with endless chains. The system extends over a distance of 5 miles in direct length, between the highest point, called Salvé, and the station at Prades. The undulations of the surface are followed, for the most part, though here and there holes are filled up, and humps are removed. The railway consists of seven inclined planes, on which two lines of way are laid to a gauge of 21⅝ in. between the centers of the rails. The rails are of Bessemer steel, 14 lbs. per yard, fished-jointed, and laid on transverse sleepers, 30 in. apart. The difference of level at the mine and Prades station amounts to 984 ft. The inclines, direct and reverse, vary from a level to 23 cent., or nearly 1 in four; they are connected by short pieces of level line. A directing pulley is placed at the end of each incline, and the system is automatic ; as the loaded wagons, descending by gravitation, draw up the empty wagons. Each wagon weighs 500 lbs., and carries a load of ½ ton. The speed is limited to 3.35 miles per hour, at which rate 300,000 tons per year can be transported. The wagons are controlled by means of four breaks with return pulleys.

The chains consist of ring-links, and weigh from 8 lbs. to 20 lbs. per yard, according to the maximum degree of tension on the different planes. The chain is supported on the wagons, and is attached to each wagon by a fork, between the sides of which one of the links enters. The chain is thus entirely supported by the wagons, and is suspended or floated (*chaine flottante*). The loaded wagons leave the chain at a distance of a few yards before the pulley, which is raised sufficiently high to lift the chain out of the fork, and arrive quietly on tables. The wagons are pushed on down a slight incline to take the next length of chain, or if it be removed at this platform, are turned aside and replaced by empty wagons.

The first cost of the floating chain system of transport amounted to £1,276 per mile. The cost for transport varied from ¾d. to 2¼d. per ton conveyed per mile. The cost for the whole distance, 5 miles, taken at 2¼d. per mile, amounts to 1s. 3d. per ton; whilst formerly the cost for conveyance by oxen amounted to 3s. 3d. per ton.

By A. Evrard: Résumé de la Société des Ingenieurs Civils.

* From James Forrest's "Abstracts of Papers in Foreign Transactions and Periodicals," for the Proceedings of the Institution of Civil Engineers.

ENGINEERING STRUCTURES.

Fire-proof Building in Vienna.—The following regulations are in force in Vienna in order to secure buildings in case of fire:—

1. When the position of a building is such as to make it desirable, as a precaution against fire, the ground floor must be vaulted. In the attic and in the first story, when the ground floor is not vaulted, the floors must be massive (as described), and a layer of dry mortar, sand, or other incombustible matter must separate the beams from the planking.

2. Stables and hay-lofts must have a fireproof ceiling.

3. Rooms for storing fuel must be, in general, located in the cellar, and built of masonry. When they are in sheds of but one story, they must, in addition, have a fireproof roof.

4. In every building fireproof stairways must communicate from the attic to the cellar, and with every dwelling by means of fireproof passages. (This implies that the vestibule should also be fireproof; and it is, in fact, invariably vaulted, and has a flooring of stone or *béton*.) In buildings of great extent there must be several such stairways, sufficient to enable all persons dwelling in them to pass readily out of doors.

5. When a stairway is lighted by means of a skylight, the frame of the latter must be constructed entirely of iron, and rest, on all sides, on masonry rising above the roof.

6. All stairways and passages connected with them must have a fireproof railing.

7. Woodwork must be removed from the interior surface of all flues by a thickness of at least six inches of masonry. The masonry of the chimneys must be plastered on the exterior, from the pavement of the attic to the highest point of the roof.

8. Each story shall be provided with at least one separate flue, passing without communication with any other to its exit at the roof. Where the beams of the floor rest upon the walls containing flues, an earthen pipe shall be inserted into the latter, having for its length at least the thickness of the whole floor, and for its thickness at least one inch. Every flue must have, at its commencement in the lower story, and also in the attic, a side opening, closed by two iron doors, closely shutting, and provided with a lock. Where several flues lie side by side, they shall be closed still further by an iron bar and padlock, extending over the openings of all. All woodwork in the vicinity of these doors must be covered with sheet-iron.

9. All roofs must be covered with tiles, slate, metal, or some other fireproof material. The woodwork of the roof must at no point be nearer than six inches to the pavement of the attic. Iron roof-frames must rest upon masonry alone; wooden cornices are forbidden.

10. The attic roof must be covered with tiles, cement, or other fireproof material. An iron door, hung in an iron frame, must communicate alone from the main stairway with the attic. At least once in every 90 feet of its length the attic must be sub-divided by a brick wall running across its width and rising 9 inches above the roof. (This is generally covered above with zinc.) The compartments ensuing shall communicate with each other only by means of iron doors hung in iron frames. No dwelling-rooms are permitted in the attics of buildings.

11. Every house shall be provided with a wall at least 6 inches thick, separating it from its neighbor—for the two houses thus ensues a wall of 12 inches.

The thickness of walls must be regulated by the weight they have to support and the material of which they are composed; also by the height of the stories and the construction of the floors and ceilings.

The following rules are to be observed:

(*a*) The principal outer walls, as well as all interior walls, at the point where they contain flues, must be at least 18 inches thick. The principal walls of the upper story must be at least 2 feet thick if the depth of the rooms is more than 20 feet. The main walls may have the same thickness in two successive stories. In buildings of three stories the main walls must, at the ground, be at least 2 feet thick; in buildings of four stories, at least 2 feet 6 inches thick. Those portions of the main wall which do not support floors can be made 18 inches thick for all stories.

(*b*) Where the ceilings are vaulted and rest on iron girders, in case the latter are not more than 20 feet long, the walls supporting them need only be 18 inches thick for all stories; where they are of greater length, the walls must be 2 feet thick.

(*c*) The foundation walls must, in all cases, be 6 inches thicker than those of the lower story.

(*d*) In light walls, the walls must be in all cases 18 inches thick where they support ceilings, or bound rooms used for dwelling purposes. In other cases, they need be only 12 inches thick.

(*e*) Walls supporting massive floorings of half or whole trees (as described) must be 2 feet thick, and the trees must rest for six inches at their ends upon the same.—*The Architect.*

ORDNANCE AND NAVAL.

THE PALLISER GUN EXPERIMENTS.—Recently Sir William Palliser, assisted by Captain Edward Palliser, made some important experiments with a view of ascertaining the ultimate strength of a gun lined with a coiled barrel, 7 in. in bore, and barely 3 in. thick. In point of fact the experiments were intended to contrast the action of coiled wrought-iron tubing in guns, under exceptionally heavy charges, with the steel-lined guns of the Woolwich pattern—the Thunderer 38-ton gun and the 38-ton gun lately burst at Woolwich being examples of the weapons against which Sir W. Palliser contrasts his system. There were present the attaches of the Russian, German, Austrian, and American Embassies.

The gun with which it was proposed to make the experiments was a weapon which has a history. It was a 10-in. cast-iron gun of 84 cwt. which served in the Crimea, and received a bruise on the side from a Russian shell and grape shot indentations at the muzzle. It was proved at Woolwich in 1839, served on the Hydra from 1847, and was employed throughout the siege of Sebastopol. Returned to Woolwich in 1856, it was sold to Sir William

Palliser in 1866, and by him converted into a 7 in. rifled gun of 95 cwt., after being variously used to try experiments with the steel lining. The steel lining having burst, Sir William Palliser has given the gun three tubes of coiled wrought iron—the first, that carrying the rifling, being ¾ in., the second the same, and the third 1½ in.—the whole encased in the cast-iron shell of the old gun. The gun was in a cell on the marshes, with her muzzle pointed into a mound of earth built round with boards. Provision had been made for the recoil by placing an incline behind the gun, up which her carriage would slide, and so utilize her weight for easing her down to the firing point, a spring buffer being placed at the top of the incline to receive what unexpended force might remain when the recoil had carried the weapon so far.

As the gun is one eighth of the weight of the 38 ton gun, it was proposed to commence the trials with the proportional double charge which burst the 38-ton gun at Woolwich. The gun was loaded with a rear charge of 13 lbs. 12 ozs of pebble powder and an 88 lb. "Palliser" shaped shot, and a front charge upon that of 10 lbs. 10 ozs. of powder and a 75-lb. shot—the whole double charge taking up about a third of the barrel's length. The charge was fired with a friction tube, and the only result was to send the timber-work flying. The bore was tested, but there was no perceptible giving of the metal. The second round consisted of 16 lbs. of powder and a 100-lb. shot for the rear charge, with 11-lbs. of powder and an 85-lb. shot for the front charge. There was more disturbance of the mound, but no great change in the bore of the gun, though the charge was much greater in proportion to that which burst the 38-ton gun. The third round consisted of 18 lbs. of powder in the rear charge and a 100 lb. shot, with 12 lbs. of powder and an 85 lb. shot for the front charge. The result of this was to throw the breech of the gun up on to the roof of the cell; but still the metal had sustained no fracture. The charges of powder for the next round were increased to 20 lbs. for the rear charge and 13 lbs. for the front, the projectiles being again 100 lbs. and 85 lbs. Sand bags were placed behind at the top of the incline to take the unspent recoil, and the gun was again found uninjured, with but little change in her bore. In the fifth round the charges of powder were increased to 22 lbs. and 14 lbs., and the charges together occupied rather more than half the tube. When the gun was fired the concussion was so great that the built-up boardings around were blown out, and when the gun was viewed in its dark cell by the light of a candle it was apparently uninjured. The bore could not be tested from the fact that the cell was blocked up by the fallen timbers.

There were no pressure guages placed inside the gun—a fact which was regretted by some members of the Government Experimental Committee present, the absence of the guages preventing accurate estimates being obtained as to the actual pressure of the charges; but the facts respecting the bearing qualities of wrought iron were plainly demonstrated.—*London Times.*

BOOK NOTICES.

PUBLICATIONS RECEIVED.

TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS (advanced sheets).

Annual Report of the Minister of Railways and Canals in the Dominion of Canada, for the fiscal year ending June 30th, 1879.

Report of the Chief Engineer of Canals of the Dominion of Canada. By John Page, Esq., C.E.

Report of the State Engineer to the Legislature of California.

Plans for the Improvement of the Ohio River. Petition of Herman Haupt and of the Pittsburgh Chamber of Commerce. Congressional Document, No. 33, Mis.

Discussions on Inter-Oceanic Canal Projects. By Ashbel Welch and Julius W. Adams.

Special Report of New York State Survey on the Preservation of the Scenery of Niagara Falls. By James T. Gardner, Director.

The following papers of the Institution of Civil Engineers have been received through the politeness of Mr. James Forrest:

"Account of Two Drainages in Ireland." By John Hill, M.I.C.E.

"The River Thames." By John Baldry Redman, M.I.C.E.

"Experiments on the Resistance to Horizontal Stress of Timber Piling." By John Watt Sandeman, M.I.C.E.

"Abstracts of Papers in Foreign Transactions and Periodicals."

CAMP AND CABIN. Sketches of Life and Travel in the West. By ROSSITER W. RAYMOND, PH.D. New York: Fords, Howard & Hurlburt.

Nothing need be said here about the author of this delightful little book, nor of his remarkable versatility. Every one who enjoys accurate sketches of the scenery and people of the West, should have the book.

The skillful and graceful drawing of the human side of the rough western character is exceedingly enjoyable. And the delicate humor throughout the series of sketches fits the book remarkably for reading aloud to young and old together.

AN ELEMENTARY TREATISE ON ANALYTIC GEOMETRY, EMBRACING PLANE GEOMETRY, AND AN INTRODUCTION TO GEOMETRY OF THREE DIMENSIONS. By EDWARD A. BOWSER, Professor of Mathematics and Engineering in Rutgers College. New York: D. Van Nostrand. Price, $1.75.

Conciseness and clearness are the prominent characteristics of this new text book.

The author has made excellent use of the methods lately developed by leading writers, and has skillfully incorporated them in the

treatise. At the same time there is no departure from the familiar order of subjects.

Among the conspicuous merits of the book may be mentioned the presentation of the symmetrical and normal forms of the equations of the right line and of the plane, the equations of the ellipsoid and of its tangent plane, and the formulas for the distances of a point from a line and from a plane. These are not usually found in American text books.

Another merit of the work which will be appreciated by instructors and students alike, is the selection of illustrative examples following each leading topic.

The author is a practical and successful instructor, and his book bears abundant evidence of it.

The mechanical execution of the work is excellent.

A TREATISE ON THE RICHARDS STEAM ENGINE INDICATOR, WITH DIRECTIONS FOR ITS USE. By CHAS. T. PORTER. Revised and adapted to American practice. F. W. BACON, M.E. Third Edition. New York: D. Van Nostrand. Price, $1.00.

The former editions of this work have done excellent service as aids to the working engineers of this country. The present edition, like the former ones, is a compact hand-book of directions, rendered in plain and concise terms, and covering all the contingencies likely to arise to applying the Indicator to use.

The practical rules for the computations have been extended, and the use of the Pantograph and the Polar Planimeter are described in the supplement which appears in this edition.

The Indicator, but a few years since, was only in the hands of a few experts, and was regarded as a piece of mechanism whose successful use was beyond the capabilities of the common engineer. It would doubtless have occupied the same position to this time but for the editor of this little volume who is one of the most widely known experts in the land. With unusual talents for instructing, he prepared a set of instructions which has created a demand for the instrument from working engineers throughout the land.

TRAVERSE TABLES. Computed to four Places of Decimals for every Minute of Angle up to 100 of Distance. By RICHARD LLOYD GURDEN. London: Charles Griffin & Company. For Sale by D. Van Nostrand. Price $12.00.

"Mr. GURDEN is to be thanked for the extraordinary labor which he has bestowed on facilitating the work of the Surveyor. . . . An almost unexampled instance of professional and literary industry. . . . As to the value of the Tables themselves, ONE OPENING OF THE BOOK, and a simple inspection and notation, WITHOUT CALCULATION, gives the information which, if sought by the usual method, requires the opening of the tables of logarithms in four different places, making two separate additions in order to get figures of second decimal places (those in the Tables being to four places), and making calculations involving the use of 48 more figures than are required to be written by the person who uses these Tables. . . . When the anxious and laborious work of one man affords the means of such a saving of toil for all those who avail themselves of his work, the patient and careful tabulator deserves the name of a benefactor of his profession, and a good servant of his fellows."—*Athenæum.*

RADICAL MECHANICS OF ANIMAL LOCOMOTION. By WM. PRATT WAINWRIGHT. New York: Published for the author by D. Van Nostrand. Price, $1.50.

The practical bearing of this book relates to the "setting up" of soldiers, but, as the author suggests, may find many opportunities for application among civilians.

The writer offers through a knowledge of the mechanism of bony and muscular systems to afford a better than the usual expedients for overcoming "that fault in the body, whatever it may be, which, in nine hundred-and-ninety-nine men out of every thousand civilized nations, tends to hinder the man from marching in a straight line, from discharging his musket without destroying his aim, from cutting perpendicularly with the edge of his sabre, and which likewise hinders him from so following in his own frame the motions of the frame of his horse that the forces be absorbed in such manner as to give no recoil from the saddle."

Throughout the book the author adheres to the plan of giving specific directions to the learner, in regard to the position and action of each separate part.

MISCELLANEOUS.

THE report of the Heberlein Brake Company, recently issued, states, that after an extended trial, the Heberlein brake, in its most recently improved form, is to be extensively adopted on the Bergisch Markisch Railway, which is one of the most extensive in Germany. It has been fitted on several trains on the Saarbrücken Railway, while on the Frankfort Railway and Lower Silesian Raiway twenty-two goods engines are about to be, or are being, fitted with the brake, the Breslau service of express trains on the latter railway having already been fitted with the brake. The report is accompanied with a statement of the result of trials which have led to its adoption in Germany and Russia.

THE Society of Swiss Engineers and Architects have recently published, in a condensed form, a paper by M. Tóth, "On the Most Recent Advances in the Construction of Tunnels, especially in Germany." In his paper Mr. Tóth gave particulars relating to forty tunnels, but in the book he has occupied himself especially with ten, which, with their lengths, are as follows: The St. Gothard, 14,920 metres; Mont Cenis, 12,233; Hoosac, 7,622; Suttro, 6,205; Kaiser-Wilhelm Tunnel, Cochem, 4,205; Dettenberg, 1,800; Spitsberg, 1,747; Sonnstein, 1,429; Zimmeregg, 1,135; Teterchen, 1,075.